RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

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1916

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GENERAL REPORT OF THE GEOLOGICAL SURVEY OF INDIA FOR THE YEAR 1915. BY H. H. HAYDEN, C.I.E., F.R.S., *Director*.

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DISPOSITION LIST.

1. During the period under review the Officers of the Department were employed as follows :—

Superintendents.

MR. C. S. MIDDLEMISS .	Reverted to his substantive appointment as Superintendent with effect from the forenoon of the 6th January 1915. Granted privilege leave for 3 months and special leave for 3 months with effect from the afternoon of the 13th February 1915. Returned from combined leave and resumed duty from the afternoon of the 16th August 1915. In charge of the Central India, Rajputana and Bombay party and left for the field on the 19th November 1915.
MR. E. VREDENBURG .	Proceeded to the field on the 20th February 1915; returned from the field on the 11th April 1915. At headquarters engaged on the description of the Tertiary *Mollusca* of Sind and Baluchistan. Accompanied the Director on a tour in Karauli State in November. Deputed to Panna State from 6th to 15th December 1915.
DR. L. L. FERMOR .	Returned from the field on the 3rd March 1915. At headquarters up to 31st December 1915.

Assistant-Superintendents.

DR. G. E. PILGRIM .	At headquarters as Palæontologist. Joined the Indian Army Reserve of Officers on the afternoon of the 12th June 1915.

MR. G. H. TIPPER .	At headquarters. Granted privilege leave for six weeks with effect from the 18th January; resumed duty on the 27th February 1915. Joined the Indian Army Reserve of Officers on the afternoon of the 10th May 1915.
MR. H. WALKER . .	Returned from the field on the 7th May 1915. Posted to Burma and left for the field on the 2nd December 1915.
DR. E. H. PASCOE .	Returned from the field on the 5th April 1915. Joined the Indian Army Reserve of Officers on the afternoon of the 30th May 1915.
MR. K. A. K. HALLOWES.	Returned from the field on the 5th May 1915. Posted to Hyderabad State and left for the field on the 22nd November 1915.
MR. G. DE P. COTTER .	Returned from the field on the 5th April 1915. Appointed Curator, Geological Museum and Laboratory from the afternoon of the 24th May 1915.
MR. J. C. BROWN .	Returned from the field on the 30th May 1915. Appointed Palæontologist from the afternoon of the 12th June 1915. Deputed to Tavoy as technical adviser to the Deputy Commissioner and left Calcutta on the 12th October 1915.
MR. H. C. JONES .	At headquarters as Curator, Geological Museum and Laboratory. Joined the Indian Army Reserve of Officers on the afternoon of the 14th May 1915.

MR. A. M. HERON .	Returned from the field on the 4th May 1915. Acted as Lecturer on Geology, College of Engineering, Poona, from 10th June to 30th September 1915. Attached to Central India, Rajputana and Bombay party and left for the field on 19th November 1915.
DR. M. STUART . .	Returned from the field on the 5th May 1915. Posted to the Punjab and left for the field on the 3rd December 1915.
MR. N. D. DARU. .	Services transferred for employment under the Indian Educational Department as Professor of Geology at the Presidency College, Madras, with effect from the 23rd June 1914.
MR. C. S. FOX . .	Granted extension of leave out of India until the date of his return to India at the close of, or during, the war. Holds commission as Lieutenant in the Royal Engineers.
MR. R. C. BURTON .	Returned from the field on the 21st March 1915. Joined the Indian Army Reserve of Officers on the afternoon of the 14th April 1915.
MR. R. W. PALMER .	Granted extension of leave to the end of the war. Holds a commission in the East Lancashire regiment.

Chemist.

DR. W. A. K. CHRISTIE.	At headquarters. Joined the Indian Army Reserve of Officers from the afternoon of the 22nd March 1915.

Artist.

MR. K. F. WATKINSON. At headquarters. Granted privilege leave for one month with effect from the 13th September 1915.

Sub-Assistants.

S. SETHU RAMA RAU . Returned from the field on the 9th April 1915. Granted privilege leave for one month and sixteen days with effect from the 28th August 1915. Attached to the Burma party and left for the field on the 23rd November 1915.

M. VINAYAK RAO . Returned from the field on the 20th April 1915. Deputed to survey the Makrai State in Hoshangabad District and left for the field on the 15th November 1915; was subsequently transferred to Tavoy, and left Calcutta on the 2nd December 1915.

Assistant Curator.

MR. A. K. BANERJI . At headquarters.

Field Collector.

BABU BANKIM BEHARI GUPTA. Left on the 24th January 1915 for Sind and returned to headquarters on the 12th April 1915.

BABU DURGA SANKAR BHATTACHARJI. Promoted from Museum Assistant on the 1st July 1915. Granted privilege leave for five weeks from the 19th November 1915.

ADMINISTRATIVE CHANGES.

Appointments and Promotions.

2. Dr. H. H. Hayden returned from combined leave and resumed his duties as Director, Geological Survey of India, with effect from the forenoon of the 6th January 1915.

Mr. C. S. Middlemiss reverted to his substantive appointment as Superintendent with effect from the 6th January 1915 on return of Dr. Hayden, from leave.

Dr. G. E. Pilgrim, Assistant Superintendent, was appointed to officiate as Superintendent with effect from the 13th February 1915.

Mr. H. Walker, Assistant Superintendent, was appointed to officiate as Superintendent with effect from 13th June to 16th August 1915.

Dr. L. L. Fermor was appointed to act as Curator from the 15th to 24th May 1915.

Mr. G. de P. Cotter was appointed to act as Curator with effect from the 25th May 1915.

Mr. J. C. Brown acted as Palæontologist from the afternoon of the 12th June 1915 to December 31st.

Leave.

3. Mr. C. S. Middlemiss was granted privilege leave for 3 months and special leave for 3 months with effect from the afternoon of the 13th February 1915.

Mr. G. H. Tipper was granted privilege leave for six weeks with effect from the 18th January 1915.

Mr. K. F. Watkinson, Artist, was granted privilege leave for 1 month with effect from the 13th September 1915.

Sub-Assistant S. Sethu Rama Rau was granted privilege leave for 1 month and 16 days with effect from the 28th August 1915.

MILITARY SERVICE.

4. Early in the year the majority of those members of the Department whose age and physical condition permitted of their undertaking military duties, applied for permission to join the Indian Army Reserve of Officers; permission was generously accorded by the Government of India to all applicants and the following officers received commissions: Dr. G. E. Pilgrim, Mr. G. H. Tipper, Dr. E. H. Pascoe, Dr. W. A. K. Christie, Mr. H. C. Jones and Mr. R. C. Burton. Messrs. C. S. Fox and R. W. Palmer had already received commissions in British regiments in the previous year, Mr. Palmer having been

at the front since September 1914 and Mr. Fox since the summer of 1915. Mr. Tipper and Dr. Christie left for the front in November and Mr. Burton in December. The remaining officers, Drs. Pilgrim and Pascoe and Mr. Jones were still in India at the end of the year.

OBITUARY.

H. S. Bion.

5. The death of Mr. H. S. Bion in June, 1915, has already been referred to in the preceding volume of these *Records*. His loss to the Geological Survey is still keenly felt, and his services would have been of special value at the present time.

R. Lydekker.

Mr. Richard Lydekker, who died on April 16th of last year, joined the Geological Survey in November, 1874, and retained his appointment for nearly nine years. In spite of the shortness of the period of his stay in India, he succeeded in completing a large amount of original work. His geological survey of Kashmir, made during the years of 1875—1881, threw much additional light on the important subject of Himalayan stratigraphy of which little was then known, and his memoir published in the year 1883 is still the standard work on the geology of Kashmir generally, having been superseded in parts only by the more detailed surveys carried out during recent years by Messrs. Middlemiss and Bion. The work for which Mr. Lydekker was best known, however, was his description of the Indian Tertiary Fossil Vertebrates; this was begun in Calcutta, but, owing to the absence of facilities for work of the kind in this country at the time, Mr. Lydekker undertook to complete his investigations after his retirement early in the year 1883, and the four large volumes of series X of the *Palæontologia Indica* ("Indian Tertiary and Post Tertiary *Vertebrata*"), published between the years 1875 and 1887, constitute a lasting monument to his scientific activity.

PROFESSORSHIPS AND LECTURERSHIPS.

Calcutta.

6. Mr. E. Vredenburg was University Lecturer at the Calcutta University throughout the year. Mr. H. C. Jones was Lecturer on Geology at the Presidency College until he joined the Indian Army Reserve of Officers, when he was succeeded by Mr. G. de P. Cotter.

Mr. A. M. Heron was lecturer on Geology at the Engineering College, Poona, from 10th June 1915 till 30th September 1915.

Poona.

Mr. N. D. Daru was attached to the Madras Educational Service on transfer as Professor of Geology in Madras throughout the year.

Madras.

INDIAN SCIENCE CONGRESS.

7. The second meeting of the Indian Science Congress was held in Madras on January 14th, 15th and 16th, 1915. The Geology Section was presided over by Dr. W. F. Smeeth, Director, Department of Mines and Geology, Mysore State; amongst several papers of interest which were offered, an especially valuable one by Dr. Smeeth himself dealt with the geological history of Southern India and summarised the results of the work done in recent years by the members of the Mysore Geological Department; this has led Dr. Smeeth to the conclusion that the Archæan rocks of Southern India, including the Dharwars, ultimately are all of igneous origin. The paper has appeared in the *Proceedings of the Asiatic Society of Bengal*, Vol. XI, Nos. 5 and 6 (May, June 1915), page 141.

POPULAR LECTURES.

8. The course of popular lectures delivered at the Indian Museum during the winter of 1914-15, included a lecture by Dr. L. L. Fermor on the "Manganese-ore Deposits of India" and a lecture by Mr. J. Coggin Brown on "Prehistoric Remains in India." A popular lecture on the Hindu Kush and the Pamirs was delivered by me before the Asiatic Society of Bengal in December.

PUBLICATIONS.

9. The publications issued during the year under review comprise two volumes of Records and one memoir of *Palæontologia Indica.*

LIBRARY.

10. The additions to the library during the year 1915 amounted to 2,523 volumes, of which 820 were acquired by purchase and 1,703 by presentation and Exchange.

MUSEUM AND LABORATORY.

Staff.

11. Mr. H. C. Jones was Curator of the Museum and Laboratory till the middle of May, when he left to join the Indian Reserve of Officers. Dr. L. L. Fermor took over charge of the duties for three weeks, and was in turn relieved on May 25th by Mr. G. de P. Cotter. Mr. Ajit Kumar Banerji was Assistant Curator throughout the year. Babu Durga Sankar Bhattacharji on return from the field was promoted to the post of Field Collector. Mr. S. Subba Iyer continued to work as Museum Assistant, Palæontological section. The post of Museum Assistant in the Mineral section, left vacant by the promotion of Babu D. S. Bhattacharji was filled towards the end of the year by the appointment on probation of Babu Baroda Charan Gupta.

Determinative work and analyses.

12. The number of specimens referred to the Curator for examination and report was 333, of which assays and analyses were made of 18. This included 67 rock specimens from the Deputy Conservator of Forests, Almora. The chemical work included an analysis of blanfordite.

Meteorites.

13. Only one meteorite fall was recorded in 1915. This occurred on the 19th of January 1915 at Visuni village, Umarkot Taluka, district Thar and Parkar, in Sind. The specimen, which was forwarded by the Collector of Thar and Parkar, is an almost complete aerolite, covered with crust except at one corner. The meteorite weighed 594 gms. Mr. H. Walker has undertaken the description and is preparing a paper for publication in the *Records*. He determines it as a crystalline spherical chondrite (cck).

14. Eight fragments of meteorites were obtained by exchange from the United States National Museum, Washington. These are:—Hendersonville (116·8 gms.), Modoc (37 gms.), Long Island (52 gms.), Holbrook (114·7 gms.), Cullison (48 gms.), Crab Orchard (40 gms.), Williamstown (132·5 gms.), Perryville (98·2 gms.). The first six of these are stones, the last two, irons. Three fragments were received by exchange from the South African Museum, Cape Town; these are:—St. Marks (83·1 gms.), Jackalsfontein (54·2 gms.) and Matatiela (78·8 gms.). The first two are stones, the last an iron. Nine fragments were presented by the Trustees of the British Museum, *viz.*, Crumlin (38·7 gms.), Oshima (233·1 gms.), Zomba

(27·9 gms.), Eli Elwah (75 gms.), Uwet (254·8 gms.), Barranca Blanca (49 gms.), Mount Hicks (64 gms.), Pan de Azucar (92 gms.), Cowra (29·5 gms.). The first four are stones, the last five, irons.

15. During the year fragments of the following Indian meteorites were despatched to other Museums:—

(1) to the Superintendent of the Government Museum, Madras, as a donation, a piece of the Kuttipuram meteorite, weighing 63 gms.;

(2) to the Keeper of Minerals, British Museum, as a donation, pieces of the following falls:—

Bholghati (28·6 gms.), Mirzapur (208·8 gms.), Lakangaon (93·8 gms.), Shupiyan (65·9 gms.);

(3) to the Director, South African Museum, Cape Town, in exchange, pieces of the following:—

Karkh (two chips, 16·9 gms.), Dokachi (70·9 gms.), Khohar (83·1 gms.).

16. A new show-case has been placed in the Meteorite Gallery, and the meteorite collection, which is now exhibited in three cases, has been entirely re-arranged in accordance with the Rose-Tschermak-Brezina classification.

Donations to Museums, etc.

17. During the year various rock, mineral and fossil specimens were given either in exchange or as donations to the following museums, educational institutions and teachers:—

(1) Redpath Museum, Montreal, Canada;
(2) Agricultural College, Nagpur;
(3) Hooghly Training School, Hooghly;
(4) Field Museum of Natural History, Chicago;
(5) David Hare Training College, Calcutta;
(6) Prof. T. W. Edgeworth David, Professor of Geology, Sidney University;
(7) Miss Burnett Hirst, 11 City Road, Allahabad;
(8) Prof. A. Lacroix, Musee d'Histoire Naturelle, Paris,
(9) St. Patrick's Catholic Church School, Cawnpore;
(10) Diocesan College, Elgin Road, Calcutta.

Additions and exchanges.

18. Of the additions of foreign specimens to the Museum during 1915, the most important is a collection of igneous rocks from Skye and Glenelg in Inverness-shire, presented by Dr. Fermor. The collection is illustrative of the various types dealt with by Prof.

Harker in his work upon the Igneous Rocks of Skye, and includes various kinds of basalt, rhyolite, peridotite, gabbro, granite, granophyre, Cambrian marble, marscoite, picrite and various specimens from the Lewisian and Torridonian systems and Moine schists.

A fine collection of specimens from the Stassfurt salt mines in Germany was received from Dr. W. A. K. Christie. This includes samples of kainite, carnallite, kieserite, picromerite polyhalite, hart-salz, sylvine and boracite.

Amongst minor additions of foreign specimens may be mentioned specimens of benitoite and of lithiophorite acquired by exchange from Mr. W. A. Roebling, United States of America, and also some gold nuggets from the Klondyke region, presented by Dr. L. L. Fermor.

A. collection of English Tertiary fossils was received from Mr. F. R. Cowper Reed.

Amongst the many Indian specimens acquired by donation may be mentioned the following:—

(1) jamesonite from Shogot, Lutko Valley, Chitral, presented by Mr. Shiv Raj;
(2) wolfram from Degana, Marwar State, Rajputana, presented by Mr. H. A. Pearson;
(3) vein quartz carrying native gold from Kundru Kocha, Singhbhum, presented by the Dhalbhum Gold and Minerals Prespecting Co., Ltd.;
(4) molybdenite from the Godavari district, presented by the Executive Engineer, Godavari, Northern Division;
(5) apatite-magnetite rock from a mine near Ghatsila railway station, B. N. Railway, presented by Mr. P. E. Billinghurst.

Re-arrangement of Fossil Gallery.

19. During the latter half of the year the Curator and his staff have been largely occupied in re-arranging the contents of the show-cases and drawers in the Fossil Gallery and of the drawers in the Mineral Gallery, and in taking stock of the collection of type fossils. The re-arrangement of the Invertebrate Fossil Gallery referred to in last year's report has been continued vigorously, but is not yet complete; many of the show-cases contained specimens whose labels required renewal, while the contents of the drawers beneath the show-cases were in need of re-arrangement. The contents of every drawer in the

Invertebrate Fossil Gallery have now been entirely overhauled by Mr. Cotter and have been catalogued and cross-catalogued in order of geological age; this task involved considerable labour, but was found to be necessary before new and better specimens could be substituted for those at present in the show-cases. It became evident also, in the course of the work, that the present arrangement had been outgrown, owing to the advances in stratigraphy made during recent years; thus, for instance, it has been found desirable to split up the "permo-Carboniferous" collections into Lower, Middle and Upper Carboniferous and Productus Limestone. With these more ambitious designs for improvement in view, a wider field of reform opened up, and necessitated a thorough revision of almost the whole gallery. This work was designed by Mr. Cotter and has been carried on by him with characteristic energy during the latter half of the year; it will, however, take some considerable time to complete. The Gondwana collection has been overhauled; the duplicates have been packed in order of stage and locality, and are now readily accessible, while the types have been re-assembled. Twenty show-cases have been allotted to the Gondwana exhibits, and in these a representative collection has been arranged, with revised generic names, where necessary; Babu Bankim Bihari Gupta, Field Collector, has done the greater part of this work and the result, when the new labels have been printed, will, it is hoped, be satisfactory.

Mineral Gallery.

20. In the Mineral Gallery, it was found that all available space for storing rock specimens in the main rock collection had been used up, and it was urgently necessary to make some room for the expansion of this collection. In addition to the main collections of rocks and minerals, there were in the gallery two collections of duplicate rocks and one of duplicate minerals, and also a collection of old unregistered specimens. The collection of old specimens was overhauled, and all that was worthless was thrown away. The three duplicate collections and the remainder of the old collection are being re-registered as one duplicate collection; this work is not yet complete. As a result there is now sufficient space for the expansion of the main rock collection at the normal rate for a period of eight or ten years.

21. Lastly the type fossils and figured specimens described in the Geological Survey publications have been checked, and the lists brought up to date.

MINERALOGY AND PETROLOGY.

Blanfordite.

22. Although blanfordite, the manganiferous pyroxene with striking pleochroism in tints of blue, carmine, and lilac, was first collected some twelve years ago, it has not hitherto been possible to subject it to chemical analysis on account of the lack of material of suitable purity and freshness. But, as mentioned on page 15, Dr. Fermor has at last succeeded in obtaining from a pegmatite at the Kachi Dhana manganese mine in the Chhindwara district material suitable for this purpose. The analysis was undertaken by Mr. A. K. Banerji, Assistant Curator, on material separated by means of Sonstadt's solution and carefully picked under the microscope. The specific gravity of the material analysed was 3·50 and the result obtained was as follows :—

	Per cent.
SiO_2	52·18
TiO_2	nil.
Fe_2O_3	20·26
FeO	nil.
Al_2O_3	5·89
MnO	3·60
CaO	4·37
MgO	3·25
K_2O	nil.
Na_2O	10·12
	99·57

Dr. Fermor finds that this analysis corresponds to a mixture of the molecules of the pyroxene group in the following proportions :—

		Per cent.
Acmite—$Na_2O.\ Fe_2O_3.\ 4SiO_2$		58·72
Jadeite—$Na_2O.\ Al_2O_3.\ 4SiO_2$		14·78
$MgO.\ Al_2O_3.\ SiO_2$	4·50	26·01
$MnO.\ SiO_2$	6·66	
$CaO.\ SiO_2$	9·08	
$MgO.\ SiO_2$	5·97	
Surplus SiO_2		0·16
		99·67

The last four silicates may be regarded as forming a mangan-augite with 13·84 % of MnO. The striking pleochroism of the blanfordite may be due to the association of the soda of the acmite molecule with the MnO of the mangan-augite. It should be noticed that the original locality for blanfordite is Kacharwahi in the Nagpur district, and that it does not follow that the composition of the mineral from this locality will prove to be exactly the same as that of the Kachi Dhana mineral. Indeed, variations in the intensity of the colouration of the specimens from different localities suggest that the mineral varies somewhat in composition from place to place.

Petrology of manganese ores of the Central Provinces.

23. During his work in the Sausar tahsil Dr. Fermor revisited three of the manganese-ore deposits described in his memoir on the subject, namely Bhurakam (Ghoti), Kachi Dhana and Sitapar. Each of these yielded further interesting information. The Bhurakam deposit consists apparently of a series of thin parallel bands from 3 to 5 feet thick. But that the deposit is really a single band folded repeatedly into an isoclinorium is shown by the presence on one side of the ore-band of a very fine-grained granulitic rock rich in spessartite and epidote, the latter being sometimes a mangan-epidote, suggesting withamite. The ore-band is composed partly of gonditic rocks and partly of manganese-ore of secondary origin formed by the alteration and replacement of spessartite and by replacement of intrusive pegmatitic rocks, often rich in spessartite. The gondite is itself often felspathic, and as the ore-band and associated granulite are completely enclosed in biotite-gneiss one would hesitate on the evidence of this locality alone to ascribe a sedimentary origin to the manganese band. But since, judging from evidence provided by other localities, this sedimentary origin is undoubted, it is necessary to suppose that the original character has been obscured mineralogically by hybridisation due to the addition of igneous material. This deposit serves, therefore, as a good example of the way in which a thin band of sedimentary rock may be folded in with igneous rocks, suffer serious mineralogical modification owing to the influence of the latter, and yet retain its physical identity as a stratum.

24. Kachi Dhana showed a fine example of intrusion of manganese ore by pegmatite with inclusion of blocks of the ore in the pegmatite, proving, as at Gowari Warhona,[1] that this type of manganese-ore

[1] Records, Geol. Surv. India, Vol. XLI, p. 5.

was in existence before the pegmatite was intruded, and adding this deposit to the list of those that may continue as far as the manganiferous rocks descend. Considerable quantities of blanfordite were obtained from some of these pegmatites, a portion of the material being fresh enough for analysis.

25. The Sitapara quarry was revisited in order to record progress and to collect a further supply of the minerals hollandite, fermorite and sitaparite. The original outcrop showed ore composed of the above minerals, with some braunite, the mineral assemblage being unique. The quarry, which shows that the deposit forms a hill buried in alluvium, had, in February 1915, reached a depth of 60 feet. It was found that ore of the above type had given place to a more normal type composed largely of braunite similar to that of Kachi Dhana and many other deposits in the Central Provinces, hollanditic ore being obtainable *in situ* only in one corner of the pit; but hollanditic ore is the predominant type in the talus-ore lying on the slope of the buried hill. It thus becomes evident that the hollanditic ore is a surface modification of the normal type of ore, although the source of the strontium contained in the fermorite is still unknown. It is probably a case of the surface concentration of constituents that were always present in minute quantities in the primary ores (*e.g.*, arsenic, another constituent of fermorite). That the braunitic ore now exposed must be regarded as a primary ore of Archæan age is shown by the fact that this particular type of ore and not the hollanditic type, has been invaded by great masses of pegmatite, which now enclose large blocks of the braunitic ore.

26. It is thus seen that Gowari Warhona, Kachi Dhana and Sitapar, all agree in proving that the main manganese-ore band was in existence before the pegmatite was intruded. The clear evidence that the special type of ore characterising the original outcrop at Sitapar was a secondary surface modification points to the possibility of such changes, though evidently to a less marked degree, in other deposits in the Central Provinces. Thus Dr. Fermor records that the Balaghat deposit shows abundant evidence of surface modification, although there is not any marked mineralogical change. It will not, however, be surprising if the finely granular hollanditic ore of this deposit comes to an end by the time water-level is reached, which will probably not be for years as the deposit is in a hill. It is interesting to note that at Balaghat there is a slow but gradual decrease in the manganese content of the ores with increasing depth of

working. This may mean that the formation of the hollandite was accompanied by a slight enrichment. On this interpretation the decrease in manganese content would be expected to cease when the primary ore zone was reached. Fortunately in many of the manganese mines this primary ore seems to be up to the standard of first-grade ore.

PALÆONTOLOGY.

Eocene mammals.

27. Messrs. Pilgrim and Cotter have completed a joint paper embodying the stratigraphical and palæontological results of their study of the fossil mammals found by Mr. Cotter in the Pondaung Sandstone of Myaing in the Pakokku district in Burma and already referred to in the last *General Report* (*Records, Geological Survey of India,* XLV, 107). The mammalian remains include species of the *Anthracotheriidæ* and *Titanotheriidæ*, and have been referred partly to the genera *Anthracotherium* and *Metamynodon*, while two new genera, *Anthracohyus* and *Anthracokeryx*, have been established for certain species which cannot appropriately be referred to *Anthracotherium*. Five fragments of upper molars, of which the genus is indeterminate but which may possibly belong to the titanotheroid genus *Telmatherium*, have been described under a new specific name *birmanicum*. As these fossils are the first mammalian remains that have been found at such a low horizon in Asia, the determination of their age must be based rather on their stratigraphical position than on the evidence to be obtained from the fossils themselves; comparison with mammalian faunas of such remote regions as Europe and America could not be expected to give reliable results. At the same time such evidence of age as the fauna affords is, according to Messrs. Pilgrim and Cotter, in entire accord with that furnished by the stratigraphical relations of the Pondaung Sandstone, which underlies the Yaw stage with *Nummulites yawensis* Cotter, *Orthopharagmina sella* d'Arch., *Velates Schmideli* Chemn., *Cypræa elegans* Desh., and *Gosavia birmanica* Dalton, an assemblage which points decidedly to an upper eocene age. Messrs. Pilgrim's and Cotter's paper appears in this part of the *Records*.

Tertiary Mollusca of Western India.

28. Mr. Vredenburg has now completed a preliminary description of new species of the Tertiary *Mollusca* of Sind; this will probably be published in a special volume of the *Memoirs* pending the prepara-

tion of a fuller and more detailed description of the whole material for publication in the *Palæontologia Indica.*

Cretaceous and eocene of Tibet.

29. In the *General Report* for last year reference was made to a memoir by M. Douvillé on the Cretaceous and eocene fossils collected in the neighbourhood of Kampa Dzong and Tüna in Tibet. It has now been decided, with the sanction of the Government of India, to publish M. Douvillé's work in the original French and it is hoped to issue it as a memoir of the *Palæontologia Indica* during the year 1916. The results of M. Douvillé's examination of the fossils are of considerable interest. It has already been pointed out in *Memoirs,* Vol. XXXVI, part 2, that the lower stages (neocomian to albian) of the Cretaceous are probably represented by certain unfossiliferous beds, the fossiliferous horizons beginning with the cenomanian which contains characteristic cephalopods belonging to the genera *Acanthoceras* and *Turrilites.* Professor Douvillé confirms most of the preliminary determinations published in that memoir and adds other forms not then identified; part of the supposed cenomanian has been removed by M. Douvillé to the turonian. A considerable number of fossils have been described from the Upper Cretaceous, including a new species of *Plagioptychus.* M. Douvillé regards as a new species the form determined by me as *Velates Schmideli* and describes it under the name *V. tibeticus*; he also regards the beds in which it occurs as Cretaceous rather than Tertiary and he has carried the boundary between the Cretaceous and Tertiary considerably higher than it was placed by me. His reasons for this appear to be based on the *Foraminifera* and chiefly on the occurrence and distribution of the *Orbitoides.*

Echinoids of the Bagh Beds.

30. M. Fourtau's re-examination of the echinoids of the Bagh Beds has led him to the conclusion that that stage is slightly older than has hitherto been supposed and that, instead of being of cenomanian age, it should be referred to the albian. M. Fourtau revises certain of the original determinations by Duncan (*Records,* XX, pp. 81-92) and re-describes seven species, of which five had been referred by Duncan to species already described either by d'Orbiguy or by Cotteau; these five M. Fourtau regards as new species, and he has therefore given them specific names; they are *Salenia Keatingei* (=*S. Fraasi* Duncan), *Cyphosoma namadicum* (=*C. cenomanense* Duncan), *Echinobrissus Haydeni* (=*E. Goybeti* Duncan). *Hemiaster Oldhami*

(=*H. cenomanensis* Duncan) and *Opisaster subsimilis* (=*N. similis* pars Duncan). M. Fourtau's paper was received in 1914 but has not yet been published as the preparation of the plates, which was undertaken by M. Gauthier in Paris, has been delayed owing to the war. It is hoped, however, that it may be possible to issue it shortly.

Namyau Brachiopoda.

31. Mr. S. S. Buckman was still engaged on the preparation of a memoir on the Jurassic brachiopods from the Northern Shan States; this work which has led to a complete reclassification—already referred to in Vol. XLV of the *Records*—of the *Rhynchonellidæ* and *Terebratulidæ* has proved to be more extensive than had originally been expected and the memoir has already extended from an estimated length of between 50 and 100 pages of the *Palæontologia Indica* to over 200; it is hoped, however, that it may be possible to issue the memoir during the course of the year 1916.

Devonian fossils of Chitral and the Pamirs.

32. Mr. F. R. Cowper Reed has very kindly undertaken, at my request, the description of a series of Devonian fossils collected by me in the course of a journey through Chitral and the Russian Pamirs in the summer of 1914. The specimens were sent to Mr. Reed last year, and he informs me that, so far, he has found among them only Upper Devonian forms. During the same journey I collected also Carboniferous and Jurassic fossils, but have not yet been able to make arrangements for their description.

Revision of Gondwana cycads and conifers.

33. A few years ago Prof. A. C. Seward suggested that it might be desirable, in the light of recent work to re-examine Feistmantel's original types of Upper Gondwana plants, more especially the cycads and the conifers; the collection was therefore forwarded to Prof. Seward, who is now studying it and hopes before long to be able to offer his results for publication by this Department.

Fossil wood from Burma.

34. At the suggestion of Professor Seward Miss R. Holden, who has been working at the Botany School, Cambridge, has offered to the Geological Survey, for publication in the *Records*, a paper by her on the fossil wood which is such a remarkable feature of the Upper Tertiary (Irrawaddian) beds of Burma. Hitherto no specimen had been completely worked out and described, partly owing to the difficulty of finding any in a sufficiently perfect state of preservation. Miss Holden

however, obtained a fairly well-preserved specimen from Gwebindon in Sagaing district, and was able to make both longitudinal and transverse sections, from a study of which she has come to the conclusion that the wood is referable to the family *Dipterocarpaceæ*, and she names the species *Dipterocarpoxylon burmense*. It is hoped to include Miss Holden's paper in the current volume of the *Records*; its issue, however, will be delayed owing to the non-arrival of the plate, the whole edition of which had been prepared in England and was presumably lost on the s.s. *Persia*.

ECONOMIC ENQUIRIES.

Building Stone.

35. The serious decay of the stone of which the Town Hall of Simla was built led to the demolition of that building and since Viceregal Lodge at Simla was also built partly of the same material, it was decided that an investigation should be made in order to determine what steps should be taken for the preservation of the latter building. The stone chiefly employed is grey limestone; this has been examined minutely by Mr. Tipper, who finds it to be crystalline and granular and to contain numerous accessory minerals, such as quartz, mica, iron pyrites, pyroxene and scapolite; cementing material is absent and there is very little interlocking of the grains. The rock has suffered from pressure which has produced either a finely crystalline structure or a rough foliated or banded arrangement of the constituent minerals. Mr. Tipper considers that the cause of decay of this rock is exposure to rain and moisture, for in protected situations the stone appears to be perfectly sound whilst the microscopical examination of the decayed material shows that the disintegration is not due to alteration of the constituent minerals, but has apparently resulted from a small amount of solution taking place round most of the calcite grains and thus leaving small spaces between them. Another rock employed in the construction of Viceregal Lodge is a soft argillaceous sandstone obtained from the Upper Tertiary beds at Kalka. Although of minor importance in the building it has suffered greatly from cracking; it has a very low degree of grain adhesion and is not suitable except for light work. Certain remedial measures have been suggested to arrest the decay of the limestone, but Mr. Tipper recommends that in all situations

which are exposed to rain or moisture generally it should be replaced by better stone such as the Sanjauli quartzite.

Cobalt.

35. At the instigation of the Director of Industries, United Provinces, enquiries were made into the feasibility of obtaining cobalt oxide from the old mines in Jaipur, which have long been shut down in consequence of the import of purer and cheaper material from abroad. The chief demand for the oxide is connected with the indigenous bangle industry for which blue glass is required. In recent years enormous quantities of bangles have been imported, first from Austria and, since the outbreak of war, from Japan. It appears that the indigenous glass manufacturers imported their cobalt oxide also from Germany or Austria, instead of from Canada, the world's chief producer. On the outbreak of war the Indian consumer was unaware that he was purchasing an article which was a German re-export instead of dealing direct with the country in which it was manufactured and he was, therefore, put to inconvenience for some time for lack of his colouring material. He was subsequently put into touch with English exporters and there has recently been no difficulty in obtaining the oxide required. In the meantime a certain amount of work has been undertaken by the Jaipur Darbar in extracting samples of ore from the mines, and specimens have been sent to the Geological Survey for examination. In view, however, of the fact that the cobalt oxide is produced as a by-product in Canada it was considered improbable that the impure local material could compete with the imported article, and it was recommended that no further steps should be taken towards re-opening the mines. The case is interesting as an example of the manner in which Germany had captured the Indian market and was even supplying it with a product practically the whole of which was produced in the British Empire.

Engineering Questions.

Landslip on Upper Jhelum Canal.

36. An extensive landslip having occurred at Mangla, the head-works of the Upper Jhelum Canal, the Secretary, Irrigation Department, Punjab, asked for a report on the local geological conditions; after inspecting the slip I arranged for Mr. A. M. Heron to spend a few days at the head-works and make a careful examination of the slip.

The result has been to show that the conditions which led to it are not likely to recur if the necessary precautions are taken.

Hill section, Assam-Bengal Railway.

37. In consequence of the damage done to the hill section of the Assam-Bengal Railway by the excessive rainfall of July 6th to 9th, 1915, the services of an officer of the Geological Survey were asked for by the Railway Board for a thorough examination of the hill-sides and cuttings. Mr. Coggin Brown was detailed to undertake this and visited the section in August last. He subsequently handed in a report in which he made various recommendations, which, if carried out, will minimise the danger of future slips.

Manganese.

38. In his Progress Report for the season under report Mr. Burton gives descriptions of numerous manganese-ore deposits, several of which have not been previously described. These latter are :—Saonri, Sailur, Chandi Nala, Garari Hurki, Chikmara, Chaukhandi, Saonghi-Atri, Bhansi, Nandgaon, Budbuda, Laugur, and Khara, all of which, with the exception of the two last-named, lie in the Katangi plain. Mr. Burton also gives notes amplifying descriptions previously given by Dr. Fermor of other deposits, and in particular supplies a series of interesting sections showing the results of over-thrusting at the Balaghat (Bharweli) manganese mine, and of the complicated folding that has affected the Thirori deposit. For various reasons Mr. Burton is inclined to refer these manganese deposits to two distinct horizons. The deposits of Balaghat, Laugur, Ukua, and Khara, demonstrably lie close to the base of the Chilpi Ghat series, the exact position in the succession of beds forming this series being given on page 38. On the other hand the deposits situated in the Katangi plain, together with associated quartzites and muscovite-schists, are folded up with gneisses in an area of generally more intense metamorphism. Dr. Fermor, in his account of the deposits of this area[1] attributed to greater general metamorphism at a lower altitude and presumed greater depth below the ancient surface any mineralogical differences that exist between these deposits and those associated with the Chilpi Ghat series in the Balaghat-Ukua syncline. The evidence is not yet decisive,

1. *Mem., G. S. I.*, XXXVII, pp. 310-314; the discovery by Mr. Burton that the conglomeratic gneiss of Ukua is an autoclastic rock does not vitiate the argument.

but as a result of his more detailed survey, Mr. Burton is disposed to regard the Katangi group of deposits, together with the associated quartzites and muscovite-schists, as belonging to his Sonawani series, the type area of which lies in the hills to the north. His chief reasons for this are (1) the presence of a thin band of calc-granulite overlying the manganese-ore band at Garari Hurki and to the east of Ponia in the Katangi plain; and (2) the existence in the Koka-dadar Lotan hill-mass, in the hills to the north of the Katangi plain, of a small outcrop of manganese-ore in contact with, and probably underlying, a thin band of calc-granulite, which may be a much-diminished equivalent of the main mass of the Sonawani calc-granulites. As these latter lie at or near the base of the Sonawani series (see *Rec. G. S. I.*, XLV, p. 132) the occurrences referred to suggest that the manganese-ore deposits of the Katangi plain should also be referred to this stratigraphical position and grouped with the manganese-ore deposits associated with crystalline limestone referred to in the previous report (l. c.).

Mr. Burton also notes a case—at Bhansi in the Katangi plain—analogous to those described by Dr. Fermor from the Chhindwara district of pegmatite enclosing fragments of manganese-ore.

Molybdenite.

39. Towards the end of the year specimens of molybdenite were received from the Executive Engineer, Godavari Northern Division, Rajahmundry. The material consisted of pegmatite, containing a considerable quantity of molybdenite, which had been obtained from a well which was being sunk at Kunnavaram, in the Rajahmundry taluk of the Godavari Agency Tract. As molybdenite is at present worth about £600 per ton and is in considerable demand for the manufacture of high-speed tool-steel, it was considered advisable to investigate the occurrence at once. Mr. G. de P. Cotter proceeded to the locality but after a careful examination of the neighbourhood has come to the conclusion that the occurrence is merely sporadic and that there is no reason to suppose that any large quantity will be found.[1]

[1] Mr. Cotter's visit to Kunnavaram was paid actually in the beginning of the year 1906 and does not, therefore, strictly speaking, fall within the period with which the present report deals, but owing to the importance of the meneral at present, it has seemed advisable to publish this information at once.

Petroleum.

40. Oil-shows were found by Mr. Cotter in various parts of the country mapped by him during the field-season in Pakokku district, especially along the Myaing anticline and near Kyaukwet (Sheet 84K-10). The structure, however, is unfavourable owing to the intense faulting. Seven miles south-west of Kyaukwet, near the village of Palangaing, there is a gentle anticline of Pegu beds rising from beneath the Irrawaddy sandstones, but it is very doubtful whether it is worth testing.

Burma.

41. On his way back to headquarters from the Northern Shan States, Mr. Brown's services were diverted for a short period to enable him to take part in a conference held at the oilfields in order to discuss the question of the advisability or otherwise of permission being accorded to the sinking of a well in the bed of the Irrawaddy between Singu and Yenangyat.

42. During the latter part of the field-season of 1914-15, Sub-Assistant S. Sethu Rama Rau examined the Uyin anticline near Allanmyo in Thayetmyo district. The fold, which can be followed for over seven miles, is an asymmetric one having a NW—SE strike which changes to E-W near Kyetyongale. Near Tebin the Pegu beds pass under the overlying Irrawaddy series.

43. During the earlier part of the year, Dr. E. H. Pascoe continued his investigation of the known oil seepages in the Punjab; he visited Jaba, Isa Khel, Mardwal, Khabakki, Khaur, Sudkal, Chharat, Murat and Misnot. Most of these localities appeared to offer no great hopes of successful exploitation, but at Mardwal and Khabakki seepages occur on an open anticline of favourable shape and with gentle dips; the rocks, however, are hard and impervious. At Khaur, where a seepage was found by Mr. E. S. Pinfold, the structure appears to be highly favourable over an extensive area and a well put down on behalf of the Attock Oil Company struck oil at a short distance below the surface. I visited the field in November and found that steps were being taken to test it thoroughly with a view to energetic development. The results of these tests will be awaited with interest, more especially as the oil occurs at a horizon considerably higher than that at which it has been found in Burma and if its present position is due, as suggested by Mr. Pinfold, to migration from lower horizons, its occurrence in any considerable quantity will very greatly

Punjab.

enlarge the field over which search for oil may be made in the Punjab with reasonable hopes of success.

Potash Salts.

44. The investigations, referred to in the last *General Report* with regard to the potash salts of the Salt Range, were continued during the year under review, first by Dr. E. H. Pascoe and subsequently by Dr. M. Stuart, the latter officer having been detailed to examine the numerous outcrops of salt which occur in the Nilawan ravine. Dr. Stuart's investigations are not yet complete, but, so far as they go, offer no great hopes of the discovery of large quantities of potash

Pyrite.

45. At Hungwe (23°7′ : 97° 11′) and near Man Pat (23°12′ : 97°11′) in the Northern Shan States, Mr. Brown found several quartz veins carrying large quantities of iron pyrites which, however, did not yield any gold or other valuable metal when subsequently assayed. The inaccessible nature of the locality renders the pyrites of no value at present as a source of sulphuric acid.

Tungsten.

46. The fact that practically the whole supply of tungsten and ferro-tungsten used by Great Britain before the war was obtained from Germany led to a great scarcity of those materials during the year 1915 and steps were taken to establish works in England for the manufacture of ferro-tungsten and tungsten steel in the country. The company known as the High-Speed Steel Alloys was formed for this purpose and works were erected at Widnes in Lancashire. In consequence of the greatly increased amount of tungsten steel required in connection with the manufacture of muni-

tions, steps were next taken to increase as far as possible the output of the raw material, and all wolfram produced in the British Empire was ear-marked for despatch to the United Kingdom; in order to provide against any possible attempt to hold up ore all shipments reaching British ports were taken over by the British Government at a fixed rate of 55*s.* per unit of WO_3 on a basis of 65 per cent ore and were distributed to manufacturers through brokers appointed for that purpose.

Tavoy.

47. The increase of price from the pre-war rate of about 30*s*. per unit to 55*s*. might have been expected to lead to a great increase in local mining activity in Tavoy, which district is the chief source of wolfram in the British Empire; this expectation was not realised and it became necessary for the Local Government to step in and insist on concessionaires fulfilling the terms of their contracts by working energetically and efficiently. For this purpose the Government of Burma appointed the Deputy Commissioner, Tavoy, whose experience of the industry had already extended over a year and half, as special officer in charge of the mining administration of the Tavoy district. It was further decided that a member of the Geological Survey should be associated with the Deputy Commissioner as expert technical adviser, and also to assist mine-owners, many of whom had no mining engineers in their employ, with advice as to the best methods by which to develop their properties. Mr. Brown's extensive knowledge and long practical experience of ore-bodies and metal mining made him eminently suited for appointment in this capacity and his selection has been abundantly justified by the results already attained. With him are also associated Sub-Assistants S. Sethu Rama Rau and M. Vinayak Rao, the one to assist Mr. Brown in the examination of existing properties and the other to search for new ore-bodies. Mr. Brown arrived in Tavoy shortly after the middle of October and by December 31st, the end of the period with which this review deals, he had made altogether over 50 inspections and this in spite of the fact that the properties inspected lie in all parts of the Tavoy district and often at a distance of 50 miles or more from Tavoy, while at the time of Mr. Brown's arrival only two properties were accessible by any road along which wheeled traffic other than bullock carts could travel. In addition to the measures taken for the inspection of the properties, a considerable labour force has been imported to meet the requirements of those local producers who are unable to import

labour for themselves. In view of the considerable increase already attained owing to the efforts of the highly efficient administrator with whom Mr. Brown is associated, it may safely be anticipated that the coming year will see a large increase in the total output from Tavoy. The most rudimentary knowledge, however, of mines and mining methods, more particularly where metal mining is concerned, must make it clear that increased output cannot be expected as the immediate result of an increased labour force, since development, which involves driving through hard rocks, such as the quartz lodes and granite of Tavoy, can only proceed at a limited pace. No great increase therefore over the output now attained can be expected for some months, until in fact a considerable amount of development has been done. The present season is also unfavourable for increased output, since water is not now available for alluvial mining and most of the output must therefore come from the reefs until May, after which the rainy season will provide water for sluicing purposes.

Mergui and Mawchi.

48. With a view to increasing the output of other districts Mr. H. Walker was deputed to inspect and report on wolfram-bearing areas in Mergui, as well as on the Mawchi mine in the Bawlake State of Karenni. It is hoped that his recommendations may lead to an increased output in these areas also.

Rajputana.

49. In the *General Report* of the Geological Survey for the year 1913 reference was made to the occurrence of wolfram near Degana railway station on the Jodhpur-Bikaner Railway. The wolfram occurs in quartz-veins in three small hills and an attempt has recently been made to extract and export the ore. I visited the locality during a recent tour in Rajputana. The hills consist chiefly of granite penetrated by a number of veins which are approximately vertical and run either NW-SE or NNW-SSE. From the plain at the foot of the largest of the three hills the veins are seen very clearly running up the face of the hill, which is about 500 feet high. The veins consist usually of coarsely crystallised mica on the outside edges next to the country, with quartz and wolfram in the centre. The wolfram, however, sometimes occurs also with the mica. The veins are usually from a few inches to a foot in thickness, but in some instances, as on the north-western side of the big hill, they are two or three feet wide. In one place on that side of the hill there is a very large mass of quartz probably 20 feet by 20 feet and of unknown depth, which contains con-

siderable quantities of wolfram. Work is being carried on now in a large number of places on the big hill and on a small hillock to the south-west of it. The veins are being worked by open quarries, but so far the amount of work done is quite insignificant and amounts only to preliminary prospecting. I was unable to ascertain the average value of the veins that are being worked, as the present workings are too small and too local to give reliable results; they are, however, sufficiently rich to make working under present conditions a profitable enterprise. Labour is cheap, unskilled workmen being paid 4 or 5 annas per diem and blasting *mistris* one rupee. Small parties of workmen are engaged at various points quarrying out the lodes, some working near the foot of the hill, others higher up and some near the top. The disposition of the lodes, which are vertical, makes quarrying a perfectly straightforward operation, but the present method of working high up on the hill-side from above downwards will no doubt be discarded when the work has extended beyond the prospecting stage, when it will be advisable to mine by means of galleries at various elevations. Most of the veins at present exposed are thin, and if the price of wolfram falls appreciably in the future, it is possible that the cost of extraction at Degana may become prohibitive, since every inch of rock has to be blasted. Mining will therefore be expensive. If we assume—which seems justifiable—that the veins are on the average as good inside the hill as they are on the surface, there is undoubtedly a considerable amount of wolfram to be had here. The amount being won at present is very small, since the concessionaires are working on quite a small scale, their output at present being, I understand, only about 1½cwt. per diem. By increasing the number of working places and by a corresponding increase of labour staff, they ought to be able to treble or quadruple their output. This they will probably do as they begin to find their feet, for it will be to their interest to extract as much ore as they possibly can while the present inflated prices continue to prevail. The future of the property will depend on the condition of the wolfram market when conditions again become normal after the end of the war. If the more superficial workings prove the veins to be continuous and fairly rich, it may ultimately pay to undertake deep mining. At present the extent of the veins is unknown; the hills in which they occur stand out in a small isolated group completely surrounded by sand and alluvium. The life of the mine will therefore ultimately depend on

the depth below the plain level to which workings can be carried profitably.

Singhbhum.

50. Specimens of wolfram, said to have been found in Singhbhum, have also been recently received by the Geological Survey.

Water.

Ranchi.

51. At the request of the Superintending Engineer, Western Circle, Ranchi, Mr. A. M. Heron was deputed to report on the possibility of obtaining an improved water supply for the Police Training College, at Hazaribagh. As the total amount of water required daily proved to be only 2,000 gallons, the matter was a simple one which hardly called for the special employment of a geologist. The steps recommended by Mr. Heron will no doubt result in the necessary increase in the existing supply.

Sambalpur.

52. In consequence of another request emanating from the same quarter, Dr. L. L. Fermor visited Sambalpur in order to advise the Executive Engineer regarding the most suitable sites for sinking wells. Part of the civil station is built on a ridge of schistose quartzites and quartz-schists of Dharwarian aspect and part of it on the Mahanadi alluvium at a lower level, the alluvium covering quartzose rocks in the vicinity of the ridge, and a series of greenish chloritic gneisses, or what is probably their uncrushed original form, a hornblende-granite, elsewhere. Sufficient water seems to be obtainable from wells sunk in the alluvium wherever this is thick; local difficulties have arisen in cases in which wells have been sunk in the elevated ground of the ridge and where the alluvium has proved to be thin and gneiss has been found close to the surface. It was recommended that one well on the ridge should be deepened as an experimental measure, whilst a site for a fresh well in the alluvium was selected. It is advisable that in future search for water here should be confined to the alluvium.

GEOLOGICAL SURVEYS.

Bombay, Central India and Rajputana.

53. The party consisted of Messrs. C. S. Middlemiss, E. Vredenburg (during Mr. Middlemiss' absence), A. M. Heron and Dr. M. Stuart.

54. Mr. Middlemiss was at headquarters and on leave during the year until the beginning of the field-season of 1915-1916; in his absence Mr. Vredenburg was in charge of the party. In December, after the joint investigation referred to below (page 31), Mr. Middlemiss returned to Idar State for a short period with the object of settling a few doubtful points that still remained undecided with regard to the geology of that area.

Mr. C. S. Middlemiss: Idar.

55. Mr. Heron continued his survey of the Aravalli region in a southerly direction by taking up the re-mapping of Kishengarh State and the British district of Ajmer-Merwara, together with a small portion of Marwar (Jodhpur) State immediately adjoining the western border of Kishengarh. The Standard (1″=1 mile) sheets of the Central India and Rajputana Survey worked on are nos. 166 and 196 to 199, of which nos. 196 and 198 are now completed except for the portions of Jodhpur State included in no. 196. Up to March 25th Mr. Heron had the co-operation of Dr. Stuart over sheets 196 to 199.

Mr. Heron: Kishengarh and Ajmer-Merwara.

56. Apart from alluvium, which presents no features of novelty, the rocks were found to consist of members of the Aravalli system to the south-east of a line running past Kishengarh city, and the Delhi system to the north-west of that line; the former, as surveyed principally in sheet 198, being a monotonous series of dark schists or granulites, composed of biotite, quartz and microcline, with a little muscovite, garnet, apatite and iron ores, and occasionally, sillimanite or (?) andalusite. A few discontinuous and lenticular patches of quartzite occur among these, but they were found to be always dark-coloured, impure and micaceous or garnetiferous, differing materially from the quartzites of the overlying Delhi system. Mr. Heron is disposed to regard these Aravalli schists as possibly very highly altered sedimentary rocks.

57. The Delhi system, chiefly developed north-west of the line of Kishengarh city, presented new and formidable difficulties owing to the presence of various new types, such that the division of them into Ajabgarhs and Alwars (as in the eastern Rajputana areas) is now no longer feasible. As the full succession is at present doubtful, it will be convenient to await the results of further work in the better exposed and more continuous sections near Beawar before going into details concerning it. Briefly the system, as at present regarded,

comprises a varied assemblage of quartzite, arkose, conglomerate, siliceous and biotitic limestone, white marble, ferruginous limestone, biotite and muscovite schists, garnetiferous schist, talc and chlorite schists, serpentine and tremolite quartzite (calc-gneiss), all arranged in more or less parallel outcrops among which the quartzites stand up prominently as elevated ridges. Most of this vast assemblage has the appearance of holding together in some sort of sequence and builds a type of country very different from the normal Aravalli country to the south-east and most of it without much doubt must be placed with the Delhis, *i.e.*, with a system separated by an unconformity, with thick conglomerate, from the older Aravalli formations

58. The igneous rocks of the area may be referred to briefly as a whole. In interest and variety they surpass those found in the Delhis in previous years. They embrace (1) fine-grained granite pegmatites with biotite, which are injected into the Aravalli schists in great profusion, producing the "migmatite" of Sederholm: these are confined to the Aravallis and are pre-Delhi in age; (2) coarse granite pegmatites with muscovite and tourmaline, which pierce both Aravallis and Delhis; (3) intrusive granite in masses of all sizes, from 9 miles wide downwards, of which Mr. Heron recognises many types according to the mineral character and degree of foliation found, some of these being post-Delhi and others pre-Delhi and truncated by the basal Delhi conglomerate; (4) the well-known elæolite syenites and related old intrusives (which Mr. Heron proposes to describe in a special paper); (5) amphibolites resembling those described in previous years in Alwar and Jaipur, and found intrusive in both Aravallis and Delhis, though best developed in the ridges of Delhi Quartzite; (6) a few other miscellaneous types, some of doubtful igneous origin, including coarsely crystalline garnet rock, serpentine, dolerite (with olivine) and a few others.

Dr. M. Stuart.

59. Dr. Stuart, besides being associated with Mr. Heron in the above-mentioned investigations, spent a short time alone near the end of the season in a limited area on sheet 198 with the specific object of mapping the lithological variations found in the parallel bands of the complicated Delhi rocks. Dr. Stuart has sent in a separate progress report on this subject and, in so far as a brief summary can do, his results have been included in the above notes referring to his work jointly with that of Mr. Heron.

60. This brief reference to the work done in Rajputana, with its implication of many abstruse problems still awaiting solution, is necessarily an incomplete statement of the numerous partial solutions and descriptions that appear in the full reports by Mr. Heron and Dr. Stuart, but which, in consideration of the extremely difficult nature of this crystalline complex, may perhaps with advantage await the fruits of fuller and more intimate knowledge before being further discussed in greater detail.

The Director, Mr. Middlemiss, Mr. Vredenburg and Mr. Heron: Karauli State.

61. While in temporary charge of the Central India and Rajputana party Mr. Vredenburg had occasion to visit certain parts of Karauli State which had been mapped by Hacket in the years 1869 and 1882; the survey had been revised by Mr. Heron during the season 1913-14 and Mr. Vredenburg found himself unable to accept the interpretation of the stratigraphy and the classification finally adopted. Mr. Heron had referred the rocks to one or other member of the Vindhyan system and believed that he had recognized all the stages between the Tirohan breccia and the Upper Bhander sandstone. As the question is one of prime importance so far as the re-survey of this part of Rajputana is concerned, it was decided that the ground should be visited by me, with Messrs. Middlemiss, Vredenburg and Heron, and the question of correlation examined in detail. On the way, visits were paid to the type section of the Tirohan limestone and breccia near Karwi in the Banda district of the United Provinces and to sections of the Gwalior system in Gwalior State. Subsequent re-examination of the rocks of Karauli made it clear to all members of the party, including Mr. Vredenburg, that the classification adopted by Mr. Heron was correct and that the contrary opinion at first held by Mr. Vredenburg was due partly to a misinterpreted section and partly to the unusual degree of induration of the Bhander sandstone in Karauli, which gives it a superficial resemblance to rocks of considerably greater age. Mr. Heron's work throughout the area visited proved to be careful, accurate and reliable.

Burma.

62. The Burma party consisted of Messrs. G. H. Tipper, G. de P. Cotter, J. C. Brown, and Sub-Assistant S. Sethu Rama Rau. Mr. G. H. Tipper, owing to an attack of enteric, when at Simla in

December 1914, was unable to proceed to Burma in the beginning of 1915. He joined the Indian Army Reserve of Officers in April 1915.

Mr. G. de P. Cotter

63. Mr. G. de P. Cotter continued the survey of the Pakokku district to the northward of the area mapped during the preceding season. A strip of country,

In general the results of the previous season were confirmed, and additional evidence was obtained to prove the establishment of estuarine and freshwater conditions at an earlier age in the more northerly region of the Irrawaddy basin.

64. Sub-Assistant Sethu Rama Rau was engaged in systematic survey work in parts of the Thayetmyo district covered by sheets 158 and 159 of the Burma Survey (1″=1 mile). During the earlier part of the the year, he examined several anticlines including those of Uyin, Kyawdo-Sanaing and Yein-Tamagyaw. The two last-named are in either the Sitsayan Shales or lower horizons and are formed chiefly of argillaceous limestone or indurated calcareous shale with subordinate bands of sandstone. The Uyin anticline was traced up to Kyebyongyi, and has been found to extend over a length of more than seven miles (see above, under *Petroleum*).

Mr. Sethu Rama Rau's work in this area was brought to a sudden and unfortunate end owing to his being attacked and very seriously injured by dacoits at Monnakon. His injuries were so serious that he was carried into hospital at Thayetmyo. I am happy to say that he has now quite recovered.

65. During the latter part of the field-season of 1914-15, Mr. Brown took up the systematic survey of the country lying to the west and north of the Bawdwin area, and succeeded in mapping some 500 square miles of new country. On his way to the field he revisited the Bawdwin mine and made a further detailed study of the silver-lead-zinc-bearing lodes; this led to some interesting results which may be of considerable importance from the economic point of view, for he has now definitely ascertained that the metalliferous lodes are confined to kaolinised and chloritised tuffs and not, as hitherto supposed, to a sedimentary series of felspathic grits; he also found evidence to show that the assumption that the ore-channel was limited by faults which had occurred after the mineralisation of the lodes, was incorrect and that the Bawdwin series of igneous rocks extended over a considerably larger area than had previously been imagined. He now considers it probable that the sediments which overlie the Bawdwin rhyolites and tuffs represent the lower part of the Naungkangyi beds of the Northern Shan States and are therefore of Lower Ordovician age.

Mr. J. C. Brown: N. Shan States.

66. After leaving Bawdwin, Mr. Brown proceeded to link up the map of that area with that of the previously mapped districts further to the south. He then continued westwards and northwards into the Tawngpeng (23°: 97°) and Mong Long (22°50′: 96°40′) areas, in order to demarcate the boundaries of the intrusive Tawngpeng granite along its junction with the mica schists of Mong Long and the Chaung Magyi phyllites and slates; the boundary with the latter series proved to be an intricate one and, in the neighbourhood of Hai-taung (23°4′: 97°13′), a great tongue of granite was found to extend to within six or seven miles of the Bawdwin metalliferous area. The granite is a coarse, tourmaline-bearing rock, frequently containing large felspar phenocrysts; it is always decomposed to a considerable depth, but is still hard enough to form the maze of branching ranges and deep ravines so characteristic of Northern Tawngpeng Basic dykes, chiefly of olivine gabbro, are occasionally found in the granite.

67. A study of the country round Lao-ka-ya (23°10′: 97°18′) and Mansak (23°12′: 97°19′) threw further light on the question of the stratigraphical position of the sediments which overlie the Bawdwin rhyolites; they were found to underlie the lowest fossiliferous members of the Naungkangyi series and to lie conformably on the Bawdwin

volcanic series; although they are unfossiliferous, their position indicates that their age is either Lower Ordovician or Cambrian. Mr. Brown has named this sedimentary group the Pang-yün stage, from the name of the river in which they are most clearly seen.

In the neighbourhood of Mong-yok (23°13′: 97°18′) outliers of Plateau Limestone were found lying directly on the much older Pang-yün stage.

Central Provinces.

68. The Central Provinces party during the field-season 1914-15 consisted of Dr. L. L. Fermor, Messrs. H. Walker, K. A. K. Hallowes, and R. C. Burton.

Dr. L. L. Fermor, Chhindwara.

69. During a short field season Dr. Fermor continued the geological survey of the Sausar tahsil of the Chhindwara district, where the formations studied were, as before, the Archæan gneisses and schists, the Infratrappeans, the Deccan Trap, and the alluvium, older and newer.

Comprised in the Archæans are two main divisions, namely orthogneisses and schists, and rocks that are partly or entirely of sedimentary origin. The orthogneisses of the Sausar tahsil are predominantly biotite-gneisses, of which there are many varieties. The predominant felspar is microcline, but oligoclase, labradorite, and orthoclase also often occur. In places these gneisses are richly garnetiferous, sometimes apparently owing to pressure, but not always so. They also occasionally contain sillimanite, but the evidence indicates that the presence of that mineral is due to pressure and is not to be taken as an index of the presence of assimilated sedimentary material. There are also numerous basic hornblendic bands, the exact relationship of which to the biotite-gneisses is not known. It may be significant, however, that these hornblendic bands gradate into a hornblende-gneiss apparently indistinguishable from the gneiss referred to below.

70. Intrusive in the biotite-gneiss is a great variety of pegmatites and granites. The former are predominantly muscovitic and the latter usually biotitic. From the latter there appears to be a gradation into the porphyritic gneisses interbanded with the non-porphyritic gneisses of the general complex, so that the porphyritic gneisses and augen-gneisses (often rolled out into streaky gneisses) may be younger than, and intrusive into, the typical non-porphyritic fine-grained biotite-gneiss of the Sausar tahsil. Excluding provisionally the

hornblendic gneisses, Dr. Fermor, regards the entire orthogneiss-granite-pegmatite complex as due to a succession of eruptions of various differentiation phases of one general primordial magma.

71. The paragneisses and schists include calc-gneisses and -granulites, calciphyres, crystalline limestones, and gonditic rocks. The origin of the various calcareous rocks, as studied by both Dr. Fermor in this area and by Mr. Burton in the Balaghat district, was discussed at some length in a previous report. The conclusion arrived at was that the calc-gneisses and -granulites are to be regarded as hybrids of a calcareous sediment and an acid intrusive. Near Jirola in the Sausar tahsil Dr. Fermor has found a series of rocks formed by the admixture of calc-granulite with the prevalent fine-grained biotite-gneiss of this area. Often the constituents of the two rocks have been imperfectly mixed and the ferro-magnesian constituents of the resultant compound rock are patchily distributed, the calc-granulite being represented by patches rich in hornblende, and the orthogneiss by patches rich in biotite. When the admixture has been more complete the hornblende and biotite are uniformly distributed, and, as the calc-granulite is itself regarded as a hybrid, the biotite-hornblende-gneiss must be regarded as a hybrid of the second order. This latter rock is of frequent occurrence in the orthogneissic complex of the Sausar tahsil, and suggests the wide distribution of altered remnants of the sedimentary calcareous series away from the main outcrops.

72. No fresh information was elicited concerning the Intratrappeans. In the previous report reference was made to the discovery of a spindle-shaped fault-block near Utekata, and to the probability that the Kanhan valley, which lies immediately to the west of Utekata, is occupied by an important fault striking SSE, with a downthrow of about 250 feet to the west. From a study of data collected in previous years in the Nagpur district to the south, Dr. Fermor deduces that this fault probably continues southward as far as the latitude of Nagpur, passing somewhere between Nagpur and Kamptee, and accounting for the fact that the base of the Deccan Trap at Nagpur lies at an elevation of slightly under 1,000 feet above sea-level, whereas the Suradevi Hills of Kamthi sandstone near Kamptee reach a height of 1,070 feet without being capped by trap. This gives the fault a length of 50 miles, but it must be left to the future to show whether it is a case of one continuous fault or of a zone of faulting. As there is no evidence that the fault con-

tinues to the north of Ramakona as a factor of any importance, it is probable that the Utekata fault-block, the long axis of which is aligned E by S, is a part of the cross-faulting marking the northward termination of the Kanhan fault. A search for the continuation of the Utekata line of cross-faulting on the west side of the Kanhan fault in the neighbourhood of the villages of Kuddam and Khajarwani proved successful, but the faulting was found to be much more complex than expected. There appears to be a total downthrow of 176 feet to the south, the algebraic sum of numerous block-faults of small throw (often only 20 feet). It is possible also that the fall in the level of the base of the Deccan Trap from about 1,300 feet at the latitude of Ramakona to about 1,000 feet at Nagpur, will prove to be the algebraic sum of a system of block-faulting bounded on the east side by the great SSE fault, to the existence of which the formation of the Kanhan valley must be attributed.

73. The older alluvium covers large areas in the Kanhan valley, is as much as 80 feet thick, and is lithologically distinguished from the newer alluvium by the presence of a great abundance of kankar, as in the case of the older and newer alluvia of the Ganges and other Indian rivers. The erosion to which the older alluvium is now being subjected indicates a recent depression of the lower reaches of the river relative to the upper reaches, with a consequent steepening of the gradient. From one of the beds of conglomerate in the older alluvium, Dr. Fermor extracted a worked Palæolithic chert core. As undoubted worked flakes of Neolithic type are commonly found on the surface of the older alluvium, we have evidence in this valley of the existence of two alluvia with corresponding periods of stone implements.

Mr. H. Walker: Betul.

74. Mr. Walker continued his survey of the Betul district, working during the greater part of the season in the country to the west and north of Chicholi at the west end of the district, and at the end of the season in the Deccan Trap ghat country forming the south-western corner of the district. The Chicholi tract is occupied by alluvium, Deccan Trap, Archæan granites (and gneisses), and an intervening formation composed of grits, with conglomerate. These grits were noticed by W. T. Blanford, who, in his account of the geology of Western India (*Mem., G. S. I.*, VI, p. 53), mapped them as Mahadevas, but evidently regarded their age as uncertain and even considered the possibility of two series having been included

under one name. Mr. Walker finds a portion of these rocks to be horizontal and a portion to be inclined, sometimes steeply, apparently as the result of faulting. He regards the two portions as of the same age in spite of certain differences, but has not arrived at a definite conclusion as to what this age is; he favours the idea that they are Talchirs rather than Lametas, which latter is suggested by many features.

75. The crystalline rocks in the Chicholi tract consist, to the north-west and north of Chicholi, principally of porphyritic granites, which have been converted into augen-gneisses in the neighbourhood of Sitadongri and to the north. Intrusive into these granites and augen-gneisses is a fine-grained acid granite; and of still later age are veins of pegmatite. Further south (between Alampur and Gondra) and east (near Bagla) the crystalline rocks are gneissose granites and schistose gneisses, all biotitic, with associated older amphibolites and lamellar quartzites in the latter area.

76. Mr. Walker has found several dykes of Deccan Trap age in the Moran River between Tendukhera and Sitadongri; one is composite and pierces basalt, whilst another encloses masses of the porphyritic granite that it traverses.

Mr. K. Hallowes: Mandla.

77. Throughout the field season Mr. K. A. K. Hallowes was engaged in separating and mapping in detail an area of the Deccan Trap flows round Narainganj in the Mandla district, completing the survey of 120 square miles of country on the lines of the work carried out by Messrs. Fermor and Fox in the Linga tract of the Chhindwara district, an account of which will appear in this volume of the *Records*. Eight flows are distinguished in descending order; of these the middle six have an average thickness each of about 108 feet. In composition all the flows prove to be basaltic, showing in every flow, although not in every specimen, signs of the presence of olivine, usually completely altered to serpentine, but occasionally fresh in parts. In texture the rocks range from fine-grained basalts to dolerites of fairly coarse grain. According to the field evidence all these lavas, irrespective of texture, must be regarded as surface flows. No evidence was obtained that any of the flows die out in the area examined, so that the work indicates once more the great fluidity of the Deccan Trap lavas at the time of eruption. The discovery of two small faults near Kekra was referred to in the previous *General Report*, but work carried out

during the remainder of the season did not lead to the discovery of any other faults, nor did Mr. Hallowes find any evidence of folding such as has been discovered in the Linga tract.

Mr. R. C. Burton: Balaghat.

78. Mr. Burton continued his survey of the Balaghat district and completed the survey of the Katangi-Waraseoni plain west of the Wainganga; he also surveyed a considerable area to the east of this river, including the western portions of the Baihar plateau. On the plateau, outliers of Deccan Trap capped by laterite were found in the Kothi Pat hill-mass between Laughar and Sarad and in the Tipagarh hill-mass north of Samnapur. The laterite is frequently bauxite of good quality, is over 100 feet thick, and is underlain by lithomargic clays 100 feet thick which pass down into the Deccan Trap, showing that this laterite has been formed *in situ*. Laterite up to 30 feet has also been formed *in situ* on gneiss and Chilpi phyllites. With the exception of the above two formations and the widespread alluvium of the Wainganga and other streams, the whole of the area surveyed is occupied by Archæan rocks, amongst which Mr. Burton recognises the following divisions :—

(1) Later intrusive granite and porphyritic gneiss ;
(2) Older, more basic, biotite-gneiss, also intrusive into the older sediments ;
(3) Chilpi Ghat series with manganese-ores ;
(4) Sonawani series.

The work on the Sonawani series, including the calc-granulites, was summarised in the preceding report; otherwise the chief interest in Mr. Burton's Progress Report is concerned with the constitution and stratigraphy of the Chilpi Ghat series. In the area examined that series crops out as a long synclinal strip from west of Waraseoni, past Balaghat, to Ukua, a total distance of some 40 miles (the Waraseoni-Bhimlat band of Mr. P. N. Bose). This syncline strikes roughly NE and has a relatively straight NW margin and a sinuous SE margin, the Chilpis being bounded on each margin by one or other of the intrusive gneisses. Along the SE margin of the syncline the Chilpis dip at relatively low angles to the NW quadrant and are separated from the underlying gneisses by a plane of overthrust which can be particularly well studied along the flanks of the ridge on which the Balaghat or Bharweli manganese mine is situated. In this ridge the thrust brings each of the three basal

members of the Chilpi series in turn into contact with the gneiss. As the latter has been converted into autoclastic conglomerates and breccias along the boundary, whilst the basement bed of the Chilpis consists of sedimentary conglomerates and grits, the junction is sometimes difficult to fix exactly. Along the NW edge of the syncline the Chilpi phyllites have been converted into sericite-schists, whilst in places the gneiss with which they are in contact has been converted by pressure into a series of biotitic sericite-schists and fine-grained crushed gneisses. As most of the biotite and felspar in these crushed rocks has been converted into sericite, we have here an interesting case of convergence of types, biotite-gneiss and sedimentary phyllite each yielding sericite-schist under the influence of pressure. The rocks at the north-western boundary of the syncline are disposed either vertically or with a steep dip to the NW quadrant. But to what extent there is actual rupture accompanied by overthrust faulting on this boundary is at present undetermined. Taking all the evidence into account Mr. Burton concludes that the thrust movement that has produced the phenomena recorded has come from the north-west.

79. As a result of the work so far completed Mr. Burton finds that the Chilpi Ghat series consists of the following beds, with the approximate thicknesses stated:—

	Feet.
1. Basement conglomerate and grits	0 to 900
2. Phyllites and jasperoid quartzites . . .	200
3. Manganese-ore	0 to 50
4. Phyllites	3,500 to 5,000
5. Blue slates, slaty quartzites, and felspathic tuffs	9 to 1,800
6. Phyllites, sericite-schists derived from phyllites, psammites, and thin felspathic tuffs . .	2,500
	6,200 to 10,450

It is anticipated that work further east may bring in still higher members of the series.

80. Of the two gneisses recognised the older is a fine-grained biotite-gneiss, and the younger a more acid porphyritic biotite-gneiss, the two being, probably, equivalent to the two main divisions recognised in the orthogneisses of the Sausar tahsil of the Chhindwara district (see page 35). The younger porphyritic gneiss forms a large batholithic mass in the northern part of the district

and disappears under the Deccan Trap of the Mandla district: to the north of the Mandla trap lies the pink porphyritic granite of Jubbulpore, which is regarded by Mr. Burton as a part of the same batholith. Near the Chilpi boundary, on its northern edge, the older gneiss often contains thin bands of kyanite-bearing gneisses, which are regarded as contact rocks produced at the time of intrusion of the gneiss into the Chilpis, when some sedimentary material must have been caught up in the gneiss.

Nizam's Dominions.

Mr. K. A. K. Hallowes: Hyderabad.

81. While progress has been made towards the completion of the geological map of India in other parts of the country, a large gap has long been conspicuous on the eastern boundary of the Nizam's Dominions in longitude 77°-79° and latitude 18°-19°. Although it is not at present desirable to take up the survey of this area in detail, it has been decided to determine broadly the distribution of the Deccan Trap and crystalline rocks respectively and so to complete this part of the geological map of India on a scale of 1″=32 miles. For this purpose, with the approval of the Government of India and the sanction of His Highness the Nizam, Mr. K. A. K. Hallowes was detailed to make a traverse across the area involved, following the eastern boundary of the trap. This work if carried out on the ¼″ scale should occupy only three or four months and should therefore be completed during the present field-season.

Sind.

82. Sub-Assistant M. Vinayak Rao was detailed to examine, and with the assistance of Babu Bankim Bihari Gupta, Field Collector, to collect from, the Manchhar beds of Sind. He mapped these beds in the Karachi and Larkana districts comprised on sheets 5 to 9, 22, 26 to 30, 46 and 47 of the Sind Survey (1″=1 mile). Mr. Vinayak Rao has submitted the following notes on the general results of his work: "The Upper and Lower Manchhars are of the same type as the Upper and Lower Siwaliks, which are their equivalents in the Punjab, but differ from them somewhat lithologically in the lower horizons. Fossils are not abundant as in the Punjab. The beds attain their maximum thickness on the Gaj, where only a few horizons of the Upper, Middle and Lower Siwaliks are present. To

the south they thin out and in Southern Sind the Middle Siwaliks are wanting. In some areas there are only about 100 feet of Upper Manchhars and 100 feet of Lower Manchhars.

"Estuarine conditions have prevailed in early Manchhar times in Upper Sind, as is evidenced by the presence of shells on the Gaj river. In these beds estuarine shells are found in the Upper Manchhars on the coast a few miles east of Karachi.

"Manchhar beds, both Upper and Lower, have been much disturbed along the flanks of the Khirthar and Laki ranges and the continuation of these hills, but eastward in the valley of the Indus and along the coast near Karachi the disturbance has not been great."

SOME NEWLY DISCOVERED EOCENE MAMMALS FROM BURMA. BY G. E. PILGRIM, D.SC., F.G.S., *Officiating Superintendent, Geological Survey of India,* AND G. DE P. COTTER, B.A., F.G.S., *Assistant Superintendent, Geological Survey of India.* (With Plates 1 to 6.)

THE discovery of Eocene mammalia in Burma has already been announced in these *Records* (Vol. XLV, p. 107), and their importance will be readily admitted, when it is remembered that they are the earliest land mammalia reported from Asia. Although the collection is somewhat scanty, we have hopes of largely increasing it by future searches.

The locality from which these specimens were obtained lies in the Myaing township of the Pakokku district. This district has now been mapped geologically as far north as latitude 21° 45′; the geologically mapped area extends southwards through the Minbu district to the north of Thayetmyo, so that we are now able to form definite conclusions as to the age of the rocks and the correlation of various sections in the mapped area.

I. STRATIGRAPHICAL POSITION.

Before proceeding to a description of the mammalian remains, it will be necessary to fix as far as possible, on the evidence both of the stratigraphy and of marine fossils, the age of the rocks which contain the mammalian remains.

We have reproduced a small portion of the geological map of the Pakokku district, but it is sufficiently large to show all the localities from which mammalian remains have been collected.

The formations shown on this map are :—

Alluvium.—Recent.

Irrawaddy Sandstones and fresh-water Pegu Sandstones.—Pliocene to Oligocene.

Pegu series, marine and estuarine facies.—Miocene and Oligocene.

Yaw stage.—Upper Eocene.

Pondaung Sandstone.—Upper to Middle Eocene (with vertebrate remains).

One of us has pointed out in an earlier paper[1] that the Burma Tertiaries, when traced from south to north are frequently found to undergo a change of facies from marine through estuarine to deposits which appear to be entirely freshwater.

As a result it is found that the Pegu series in the anticline of Yenangyat, where Pegu rocks commence to outcrop at a point some 20 miles SSW of Myaing, contain an abundance of marine fossils, and can be sharply differentiated from the Irrawaddy series above them, while at Myaing, these rocks are entirely fossil-wood-bearing sandstones of a type impossible to distinguish from the Irrawaddy series. So remarkably do the Pegus of the Myaing area simulate the Irrawaddy rocks that one of us in an earlier visit to Myaing erroneously correlated the freshwater Pegus with the latter, and the marine Yaw stage with the marine Pegus of Yenangyat.[2]

This erroneous correlation was mainly due to the fact that practically nothing was then known of the fauna of the Burma Eocene and its points of difference from that of the Pegus above, and also because the geological map of Burma was then a patchwork of small isolated areas, examined, not so much in order to obtain scientific results as in the hopes of discovering new oil-fields. Subsequently one of us described the Ngape section in the Minbu district, and made collections from the top of the Pegus down to the Eocene.[3]

In the Ngape section, the dividing line between the Eocene and the Pegus was drawn above a zone containing species such as *Velates Schmideli*, *Cypræa elegans* and other molluscs of a distinctly eocene type and not found in the beds above. No unconformity was actually found between the two divisions, although at the time, owing to a belief that the two divisions were unconformable in Lower Burma, it was thought possible that a stratigraphical gap might exist along with apparent conformity.

In 1913, one of us examined a full section from the Irrawaddy Sandstones to the Middle Eocene, exposed in the south of the Pakokku district in the country traversed by the Yaw river. Here the Pegus were found to be represented by estuarine or freshwater beds, while a zone of clays underlying them contained a rich marine fauna, the species of which were found to be identical with those from the *Velates Schmideli* zone in the Ngape section. These clays

[1] Cotter: Coal Seams near Yaw River, *Rec. Geol. Surv. Ind.*, XIV, p. 166.
[2] See Pascoe, Oil-Fields of Burma, *Mem. Geol. Surv. Ind.*, XL, p. 138.
[3] Cotter; Pegu-Eocene Succession in Minbu, *Rec. Geol. Surv. Ind.*, XLI, p. 221.

were termed the Yaw stage[1], and were placed in the Upper Eocene, on the evidence of their included foraminifera and mollusca. In 1914 our colleague, the late Mr. H. S. Bion, mapped the intervening country between the Yaw river section and the Ngape region, and found that the Velates zone of Ngape comes stratigraphically on the top of the Yaw stage.[2]

The Yaw Stage is regarded as eocene owing to the presence of the following *foraminifera* and *mollusca* :—

> *Nummulites yawensis* Cotter, *Orthophragmina sella* D'Arch., *Velates schmideli* Chemn., *Cypræa elegans* Desh., *Gosavia birmanica* Dalton,[3] and many other species as yet undescribed, but which one of us hopes to figure and describe at some future date. Up to now the study of these molluscs leads to the firm conclusion that an upper eocene horizon is being dealt with.

The Yaw stage in the Myaing area is only sparsely fossiliferous, and shows many signs of the increasing shallowness of the water in this more northerly region. Fossils have, however, been found and include the following :—

Orthophragmina sella D'Arch.
Operculina sp. 1.
Gosavia birmanica Dalt.
Cypræa elegans Desh.
Chama sp. 1.
Cardium spp. 1 and *2.*
and also one specimen of a nummulite which is probably *Nummulites yawensis* Cotter, form *A.*

All the above species are characteristic of the Yaw stage of the type area, and they are enough to prove on palæontological grounds the eocene age of the beds from which they come and the probable identity of these shales with those of the Yaw river. The stratigraphy also shows that this view is correct. The Myaing exposures of Yaw Shales and Clays emerge from beneath the fresh-water Pegus about ten miles to the south of Myaing, and from there the outcrop

[1] Cotter: Notes on the value of Nummulites as Zone-Fossils, *Rec. Geol. Surv. Ind.*, XLIV, p. 53.
[2] Cotter: Coal-seams near Yaw River, *Rec. Geol. Surv. Ind.*, XLIV, p. 164.
[3] See Dalton, Geology of Burma, *Q. J. G. S.*, LXIV, p. 632, where the species is described as *Voluta* (?) *birmanica* sp. nov. It must, however, be regarded as *Gosavia* owing to its pleurotomid sinus.

runs north-westward, but has not yet been mapped northwards of latitude 21° 45′. It is separated from the Yaw stage outcrop of the Yaw river (which has been traced northwards to the above-named latitude) by a syncline of Pegu and Irrawaddy beds.

The two outcrops are 11 miles apart at the northern edge of the mapped area and, as they steadily approach each other as one goes north, there is no doubt that when the country to the immediate north is mapped, we shall be able to join them up as one and the same. Meanwhile, it is sufficient to observe that the sequence of beds on either flank of the syncline also shows clearly that the Yaw stage of the Myaing area is, lithologically as well as palæontologically, the same as the Yaw stage of the type section through the Yaw river.

In the area shown in the map accompanying this paper, the Yaw stage is of a somewhat earthy facies and contains fossil wood. In places it is difficult to define its limits, since it is not so sharply differentiated from the beds above and below as it is elsewhere. Nevertheless it is the most easily recognised horizon, being in this area the only zone in which marine fossils can be found. Both above and below the Yaw stage the beds are mainly freshwater. From the Pegu beds above the Yaw stage, about 12 miles WNW of Myaing, near a village named Kyaukwet, two fragments of molars of *Cadurcotherium* were found by Mr. Lister James, owing to which occurrence one of us suggested an Aquitanian age for the beds in which they were found.[1] Unfortunately this area has not hitherto yielded any more specimens of mammalia.

The beds from which the second co-author of this paper has discovered mammalian remains lie immediately below the Yaw Clays. In the Yaw river area the corresponding beds have been termed the Pondaung Sandstones,[2] a name which we propose to use also for the bone-bearing beds of the Myaing area immediately underlying the Yaw Clays. These Pondaungs however differ in aspect from those of the Yaw river section and the Pondaung hill-range, in that, while the latter are massive sandstones with occasional shaly bands or seams of impure coal, the former are characterised by interstratified bands of highly coloured earths. In many exposures one observes successive beds of cherry-red, bright buff and cream-white earths interstratified with brown or buff sandstones.

[1] Pilgrim: Tertiary Freshwater Deposits of India, *Rec. Geol. Surv. Ind.*, XL, p. 197.
[2] Cotter: Coal-seams near Yaw River, *Rec. Geol. Surv. Ind.* XLIV, p. 165.

The feature is so marked that Mr. T. G. Bailey, who some years ago examined the Myaing anticline, called these beds the "Colour-Band series."

As, however, there is no doubt that these beds are the equivalents of the Pondaungs of the Yaw river section, there appears to be no advantage in adopting another name to denote the bone-bearing beds of the Myaing area. The bones are found lying on the surface of the ground on, or close to, the outcrops of cherry-red earthy bands. They are extremely sparsely scattered and usually in a very fragmentary condition. One tooth was found in two interfitting fragments, but the interfitting surfaces had been covered with a matrix of sandstone, showing that the tooth must have been broken at the period of deposition. The collecting of teeth is necessarily a slow and tedious process owing to their rarity.

The basal bed of the Pondaung Sandstones in the Myaing area is a very coarse conglomerate, in which the boulders largely consist of igneous rock. Some gneissic and schistose boulders are also present.

The hills of Natsin Taung and Myaing Taung are composed of this boulder conglomerate, the boulders being for the most part of igneous rock, usually an altered dolerite.

The bone-bearing cherry-red earthy beds all occur in the upper part of the Pondaungs above the basal conglomerate.

The localities in which mammalian remains have been found are shown on the map (Plate 1) by crosses marked V.F. The localities are registered in the Geological Survey Fossil Register as follows:—

(1) ¼ mile W. of Pangan village	K. 18/824—830
(2) ¾ mile W. S. W. of Pangan	K. 18/831—832
(3) 3 furlongs N. W. of Thanudaw village	K. 18/833—834
(4) ⅓ mile E. of Thanudaw	K. 18/835—837
(5) 1 mile E.N.E. of Thanudaw	K. 18/838
(6) 1 mile N. of Myaing	K. 18/839
(7) 1¼ miles S. of 1133ft. hill	K.18/840—843
(8) ¾ mile W. S. W. of 1133 ft. hill	K. 18/844—850
(9) Found by coolie near 1133 ft. hill	K. 18/851

In determining the age of the mammalian remains, we cannot conjecture with any degree of accuracy to what stage they belong from the evidence of the teeth themselves. This is due to the fact that we have no mammalian fauna of a similar age in Asia, and it is therefore necessary to compare them either with the more recent fauna of the Bugti Hills or to seek in America or Europe for allied

species. It is therefore necessary to return to the evidence of the marine fossils of the overlying Yaw stage, which, as far as we can conjecture, is the uppermost stage of the Burma Eocene, and also to remember that the total thickness of the Burma Eocene in most sections does not fall far short of 20,000 ft. The Yaw stage and the bone-bearing beds of the Pondaungs come within the uppermost 5,000 ft. of the series; therefore it is probable in so rapidly deposited a series, that the Pondaungs are not very much older than the overlying Yaws, and that if the latter are Ludian in terms of European nomenclature, the former are not probably older than Bartonian, while if the latter are Bartonian, the former would be not older than Auversian. We are not at present prepared to say with what exact European sub-stage the Yaw Clays correspond, but believe them to correspond with some part of the Upper Eocene, that is the Auversian, Bartonian and Ludian stages.

The geological map reproduced with this paper was made while the mammalian teeth were being collected, during December 1914 and January 1915. Previously the Myaing area had also been examined by one of us in 1907 and 1908, and we have also on file in our office a map which embraces portion of the area reproduced, which was prepared in 1911-12 by Messrs. R. D. Oldham, T. G. Bailey and E. S. Pinfold who examined part of the neighbouring country on behalf of the Indo-Burma Petroleum Company. This latter map has been of assistance to one of us when surveying the neighbouring area of Kyaukwet, but in the portion here reproduced for publication, the greater part is uncoloured in the above-mentioned geological map; moreover there are very many points of difference, and the whole survey has been done by one of us entirely *de novo*. While therefore we wish to acknowledge the assistance obtained from this earlier map in unravelling the general structure of this and the neighbouring country, we must at the same time accept the entire responsibility for the actual mapping of the area reproduced in Plate 1.

II. DESCRIPTION OF FAUNA.

The specimens collected include five fragments of toothed pharyngeal arches of fishes, fragments of the carapaces of tortoises, and numerous teeth and bone fragments of mammals. These last include remains of Anthracotheres, a species of amynodontid rhinoceros, and fragments of a Titanothere.

Anthracotheriidæ.

The family of the *Anthracotheriidæ* dominates the fauna of the Pondaung sandstones to such an extent that some 95 per cent. of the total number of specimens contained in the present collection belong to it. This preponderance can be illusory only in as much as the fauna was doubtless one which inhabited the plains and marshes in the neighbourhood of great rivers and from which most of the species of the forests and uplands were excluded. Since, however, similar conditions tend to prevail in all river deposits, we may fairly claim that the extent to which the Anthracotheroids are represented in this formation is excessive when compared with any other fauna at present known to us, with the exception of that of the Upper Aquitanian beds of the Bugti hills, which probably equals it.

In discussing the significance of this feature one of us has called attention to the indication, afforded by the Bugti fauna, that the family may have originated in Asia[1].

So far as the *Anthracotherium* branch of it is concerned this latest find in Burma supplies additional evidence that this view is correct, *Anthracotherium dalmatinum* being the sole representative of the branch in the Upper Eocene or Lower Oligocene of Europe. The age of the European form is disputed, but a full discussion of this question is to be found in a paper by P. Oppenheim. We are disposed to believe with Oppenheim that the species is Upper Eocene in age[2].

The evidence as to the origin of the *Ancodus* line is less clear since the Upper Eocene or Lower Oligocene beds of the Fayum, have yielded many species belonging to this particular branch.

As in the case of the Bugti fauna such changes as it is possible to ring on the ordinary *Anthracotherium* type are here exhibited in fairly considerable variety both as regards size and structure. Without multiplying species unduly it seems absolutely necessary to divide the Pondaung *Anthracotheriidæ* into at least seven species. For three of these we are unable to find an appropriate place in the genus *Anthracotherium* as defined by Stehlin and as represented by the known European species. We therefore propose to separate these under the new generic name of *Anthracohyus*. The type of the genus is the upper molar of *Anthracohyus chœroides*, and the co-

[1] Pilgrim: Vertebrate Fauna of Bugti Hills: Pal. Ind., New Ser., Vol. IV, Mem. 2, p. 40.

[2] P. Oppenheim, *Centralblatt fur Mineralogie etc.*, 1902, pp. 286 sqq.

type the mandible and lower teeth provisionally assigned to the same species. The entire absence of parastyle and metastyle and the exceedingly feeble mesostyle takes all appearance of selenodonty from the outer portion of the crown, the paracone and metacone appearing as bunodont cusps fringed by a cingulum at their base.

In *Anthracohyus rubricæ* and *A. palustris* the mesostyle is stronger but parastyle and metastyle are equally absent, so that, although the beginnings of a selenodont condition can be traced, still the outer cones are far more bunodont than in the genus *Anthracotherium.* In the mandible referred to *Anthracohyus chæroides* the small premolariform lower canine, laterally compressed, with anterior and posterior blades, is very distinct from the large conical canine of *Anthracotherium.* Equally so are the crowded lower incisors, without any indication of a diastema, which testify both to a greater breadth of muzzle and to an entire absence of the elongation which is so characteristic of the genera *Anthracotherium* and *Microbunodon.*

In the species *Anthracotherium pangan* the selenodont condition of the outer portion of the crown of the upper molars is fully established. We are therefore unable to separate it from the genus *Anthracotherium* on the scanty material which is at our disposal although the outer styles are less prominent than in the hitherto described species of that genus. The species *Anthracotherium crassum* provides evidence of a transition from the one type into the other.

At the same time the distinct elevation of the cingulum into a parastyle makes it difficult to separate it generically from *A. pangan.* We have before us, then, a series of upper molars exhibiting an almost complete passage from *Anthracohyus chæroides* at one end of the line, with primitive bunodont outer cones, to *Anthracotherium pangan* at the other, where the outer cones have assumed the regular selenodont anthracotheroid condition. It is, of course, possible that the structure of the mandible and of the canine teeth may approximate to that of *Anthracohyus chæroides* rather than to that of the European species of *Anthracotherium,* in which case these species would provide us with an even more complete transition from the one genus into the other than we are at present aware of. Further collecting will, we hope, supply material which will shed additional light on these and other doubtful points.

The remaining three species are of small size and have the outer styles fairly well developed, but have no elevation on the cingulum just anterior to the protocone (protostyle). They agree very nearly with the European genus *Microbunodon*, and with the Lower Siwalik upper molars referred to the species *Microbunodon silistrense*. Pm^3 in one of the Pondaung specimens is, however, a much longer tooth than in the European species of *Microbunodon*, and has an altogether different structure, its inner cusp approximating in character to that of *Anthracohyus*. This tooth is unknown in the Siwalik *Microbunodon silistrense*. Insufficiency of material makes it difficult to discover the true relations of these forms both to the Siwalik as well as to the small European anthracotheroid species.

Since, however, the elongated shape of pm^3 and the structure of mm^3 clearly distinguish our Pondaung species both from *Microbunodon* as well as from the genera *Rhagatherium* and *Haplobunodon*, while the presence of a parastyle in the upper molars and the greater development of the outer styles generally, as well as the absence of a protostyle, make it impossible to assign them to *Anthracohyus*, and since the triangular shape of pm^3 and mm^3, and the absence of a protostyle in the upper molars,—apart from their minute dimensions strongly militate against a reference to *Anthracotherium*, we seem to have no choice except to make them the type of a new genus for which we propose the name of *Anthracokeryx*. The generic position of the Siwalik species *Anthracotherium silistrense* and *Anthracotherium mus* must remain unsettled until further material is available and especially until the pm^3 of these species becomes known.

One may in any case infer that in the Pondaung sandstones we see the representatives of an extremely early bunodont type of *Anthracotherium* side by side with the selenodont type, which arose from it. At the next lower geological stage the former type possibly held entire possession of the field. It does not, however, appear to have penetrated to Europe, *Anthracotherium dalmatinum* being even more selenodont than *Anthracotherium pangan* of the Pondaungs. The obvious conclusion is that the Monte Promina species represents a migratory type from Asia, where alone its assumed predecessors have so far been found.

One additional feature in this portion of the Pondaung fauna seems to possess an undoubted significance. The entire absence of any quadricuspid anthracotheroid upper molars indicates that this type of anthracotheroid upper molar had not yet come into existence,

and that the 5-cuspid condition was the original one, the 4-cuspid upper molar arising subsequently, either by atrophy of the protoconule or by its fusion with the protocone. One of us at one time expressed his adherence to the contrary view,[1] but has long since abandoned it in favour of the more generally accepted opinion, in support of which the Pondaung fauna now supplies strong testimony.

The new genus *Anthracohyus* may be defined as follows:—

Upper molars.—5-cuspidate, paracone and metacone markedly bunodont on account of the entire absence of a parastyle and metastyle, and the very feeble development of a mesostyle. A cingulum encircles the cusps externally, as well as on the anterior and posterior margins.

Upper premolars.—Pm^4 bicuspid, both cusps bunodont, cingulum external, anterior and posterior; pm^3 triangular, longer than broad, pointed anteriorly, main cusp with anterior and posterior ridges opposite to one another; inner cusp strong, connected by cingula to the main cusp, but without any broad flattened area between it and the main cusp.

Lower molars.—Cusps rather bunodont, hinder arm of the postero-external crescent not uniting with the postero-internal cusp. Thus the valley between the two posterior cusps is convex; m_3 talon showing a distinct division into two cusps.

Lower premolars.—Pm_4 elongated, main cusp with anterior and posterior ridges, inner ridge separated by a groove from posterior ridge, small flattened area between the two ridges at the hinder end of the tooth, a slight cingular cusp anteriorly, anterior premolars elongated, main cusp laterally compressed with two blades but without inner ridge, a faint posterior cingular cusp.

Lower canine laterally compressed, premolariform, only slightly larger than pm_1.

Lower incisors three, strongly compressed between their convex buccal and concave lingual surfaces, crowded together without a diastema, incisor region of the jaw bread and not elongated.

[1] Pilgrim: Vertebrate Fauna of Bugti Hills, p. 41.

ANTHRACOHYUS CHŒROIDES n. sp.

(Pl. 2, figs. 1—4.)

The type of the species and genus is the isolated upper molar (G. S. I. No. B. 603) figured in Plate 2, fig. 1. Its dimensions are given in the table on p. 64. The tooth is well preserved and the summits of the cusps are distinctly touched by wear. On the front wall of the tooth there is a very pronounced facet of wear, while on the hinder wall such a facet is undoubtedly absent. We take this as an indication that the tooth is the last upper molar. If this be not the case then the animal to which this tooth belonged was extremely immature and m^3 must have been entirely *in alveolo*, a supposition which is somewhat at variance with the degree of wear on the tooth before us. On the other hand the absence of the small heel which is present in the m^3 of the other species of *Anthracohyus* and *Anthracotherium* is here absent, the breadth index of the tooth being therefore very large. This can, however, hardly be regarded as an insuperable objection seeing that it is not a universal condition in the Anthracotheroids.

Of the five cusps the only ones which can be said to show any real tendency to selenodonty are the hypocone and the protoconule. Slight antero-posterior ridges descend from the summit of the paracone and metacone and a faint ridge descends from the summit of the protocone in the direction of the metacone. There is no cingulum internally, but on the anterior and posterior bases of the tooth it is very distinct, rising into a small protostyle between the protocone and the protoconule. A cingulum runs round the base of both paracone and metacone but without being elevated into anything that could be termed a parastyle or a metastyle. The two cingula bend round opposite the median transverse valley of the tooth and unite between the paracone and metacone, but without strengthening appreciably or uniting with the antero-posterior ridges of the two outer cones which have been mentioned above.

3rd upper premolar. (B 604) A single well preserved specimen of this tooth (Pl. 2, fig. 2) is provisionally placed here. It can be distinguished in no respect except by its smaller size from the large pm^3 (G. S. I. No. B. 608) figured in Plate 3, fig. 8, and which on account of its considerable dimensions can only belong to the largest Anthracotheroid which has been found in these beds—*Anthracohyus palustris*.

Since the upper molars of this species cannot be separated generically from that of *Anthracohyus chœroides*, the present small pm^3 must also be that of an *Anthracohyus*, and since in size it agrees sufficiently well with the type m^3 of *Anthracohyus chœroides* the provisional determination seems to us to be justified.

The specimen possesses a strong main cusp connected to the anterior and posterior ends of the tooth by sharp ridges which terminate in small cingular cusps of which the posterior one is the larger. A low, but extremely well marked and isolated inner cusp is situated slightly behind the mid line of the tooth. It is connected by cingula both to the anterior and posterior cingular cusps just mentioned. There is no external cingulum. The tooth tapers in front and is almost perfectly triangular in outline, the margin between the inner and anterior cusps, and also that between the inner and posterior cusps, being distinctly concave, the latter rather less so than the former. The corresponding tooth in the European species of *Anthracotherium* is trapezoidal rather than triangular in outline, both because there is a considerable antero-external bulge on the outer side of the main cusp, and also because there is a marked flattened area or shelf between the internal and the posterior cusps. These conditions are still more pronounced in *Brachyodus* and *Ancodus* and in the merycopotamine members of the family. *Anthracotherium bugtiense* possesses a more elongate pm^3, and no very distinct inner cusp is present, but the trapezoidal shape is quite as clear as in the other species of *Anthracotherium*.

It should further be noticed that, whereas in the present tooth the line connecting the anterior and posterior ridges is parallel to the antero-posterior axis of the tooth, in *Anthracotherium*, and still more in *Brachyodus*, this line follows a direction oblique to this axis.

Mandible.—The specimens figured in Plate 2, figs. 3 to 3e and 4 to 4e (G. S. I. No. B. 605) represent the entire lower dentition on the right-hand side of a single individual. Though the teeth in front of pm_4 are detached from the jaw, there is no doubt that they belonged to the same ramus, of which the hinder portion is figured in Plate 2, figs. 3 and 4, since they were all collected from the same spot, where they were only slightly separated from one another by the weathering influences which had disintegrated the bone of the mandible. No upper molars, which have any claim to be referred to the same species as this mandible, have been found in the collection, except the one which has been just described, and which we have assumed to be

the last upper molar. The mandible is therefore provisionally referred to the species *Anthracohyus chœroides*, and may be taken as the co-type of the genus, at least until convincing evidence is forthcoming that another mandible of an entirely distinct type should be associated with the type molar of *Anthracohyus chœroides*, a contingency which the writers regard as unlikely.

There are various other specimens of the mandible, which, though showing slight variations in size, may be referred to the same species.

The mandible is shallow and rather stout as compared with that of *Anthracotherium*. The lower margin is slightly bowed beneath m_2, but whether it was notched beneath m_3 or whether there was a descending process is unknown.

Lower molars.—These are of the usual *Anthracotherium* type, the failure of the posterior arm of the postero-external cusp to unite with the opposing postero-internal cusp distinguish it from *Brachyodus*. The greater breadth of the tooth in its hinder part and the rather greater elevation of the cusps, remind one of *Telmatodon* rather than of *Anthracotherium*. The talon of m_3 has the shape of a broad loop, the hinder portion of which is much more elevated than the remainder and is distinctly divided into two cusps. The origin of the talonal loop, due to the fusion behind of two cusps each connected by a crest to the anterior part of the tooth, is rendered very evident, and is still more clear in the species *Anthracohyus palustris*. This double cusp is confined to the genus *Anthracotherium* amongst the *Anthracotheriidae*, the double cusp which one of us has mentioned in the species *Brachyodus giganteus* being rather different to this.[1]

Lower premolars; pm_4 is a long narrow tooth having a single main cusp and very minute cingular cusps in front and behind. From the summit of the main cusp ridges run down anteriorly and posteriorly. A short distance to the inside of the latter ridge is another ridge separated from the first by a narrow groove. Between these two ridges is a small flat cingular area. Thus in general structure this tooth resembles that of *Anthracotherium*. While, however, the inner wall of pm_4 in the European species of *Anthracotherium*, between the front ridge and the internal ridge, tends to be concave, here it is quite convex. It differs little from the corresponding tooth of *Anthracotherium bugtiense* except that it tapers more in front than the latter and is destitute of the strong anterior cingulum of the Bugti species.

[1] Pilgrim: Vertebrate Fauna of Bugti Hills, pp. 50 and 55.

Pm_3 is still more elongated than pm_4, and the only trace of an inner ridge is a minute fold which leaves the posterior ridge just before it reaches the hinder cusp. No anterior cusp can be said to exist and the posterior cingular area is diminished almost to vanishing point. Pm_2 resembles pm_3 very closely; there is, however, no vestige of any inner fold, only a very minute posterior cusp, and no anterior cusp. The summit tends to overhang the hinder part of the tooth so that the hinder blade is concave. Pm_1 is smaller than pm_2 but differs from it in no essential features.

The canine is small, being very little larger than pm_1 and differs from it only in being one-rooted and having an exceedingly concave hinder blade; the front blade shows a small facet of wear near the base of the tooth.

The incisor region is represented by three teeth in close juxtaposition to one another, of which only two are provided with crowns. The one of which the root only is present is probably the right i_1 and the other two the left i_1 and i_2.

Each tooth has a convex buccal surface and a slightly concave lingual surface, being strongly compressed between these surfaces. As the three teeth are in practically one straight line parallel to their longer axes, and as i_2 has a facet of wear on its proximal edge it is clear both that there was no elongation of the incisor portion of the jaw as in *Anthracotherium* and *Microbunodon*, the incisor teeth being crowded together without any diastema, and also that the front of the jaw must have been broader than in those genera.

This conformation of the incisor region, and the lateral compression and small size of the canine, seem to afford ample grounds for assigning the mandible to a genus different from any hitherto known Anthracotheroid.

As there is no reason to suppose that any other type of mandible than this should be associated with the upper molar of *Anthracohyus chœroides*, we consider that we are justified in provisionally referring it to the same genus, and also, since the mandible agrees in size and in height of cusps with the upper molar, to the same species, as the latter.

ANTHRACOHYUS RUBRICÆ n. sp.

(Pl. 2, figs. 5—7 and Pl. 3, figs. 1—6.)

As in the case of *Anthracohyus chœroides* the upper molars are chosen as the types of the species. The well-preserved m^3 and m^2

figured in Plate 2, figs. 5 and 6 (G. S. I. Nos. B. 609, B. 610) come from the same locality and probably belong to the same individual. Assuming that the type of *Anthracohyus chœroides* is m^3, the present species differs from it by its much greater size and by its much smaller breadth index, due chiefly to the presence of a sort of heel produced by the prolongation of the posterior arms of the metacone and hypocone to form two small cusps. Without this heel, however, the breadth index of the upper molars of this species would still be less than that of *A. chœroides*, as may be seen in the case of m^2 where the heel is absent. Although these upper molars agree with *A. chœroides* in the entire absence of a parastyle, a distinct mesostyle is present to which the arms of the paracone and metacone are connected. Thus both of these cusps are more selenodont than in the former species. No other points of difference separate the upper molars of these two species from one another.

From the same locality as the upper molars just described come a pm^4 (G. S. I. No. B. 611, Pl. 3, fig. 3) and a portion of a lower molar which probably belong to the same individual as the molars. Pm^4 is a bicuspid tooth with a cingulum externally, posteriorly, and anteriorly, the first named being the strongest. No parastyle is present; consequently the selenodont condition of the outer cusp which is visible in the European species of *Anthracotherium* is here entirely lacking, the cusp being almost conical except for the anterior and posterior ridges. There appears to be no trace of a median anterior cusp.

Lower molars (G. S. I. Nos. B. 612, B. 613, Pl. 3, figs. 4 and 5).—Except that the talon of m_3 is a little shorter than in the species *A. chœroides*, and the molars are perhaps a little stouter it does not seem possible to draw any distinction except one of size between the lower teeth of these two species.

It should be remarked that the m_3 and mandibles figured in Plate 3, figs. 4 and 5, seem too small for the type upper molars and it is not impossible that they may belong to another species. Still the variations in size of the same anthracotheroid species are considerable, if we may judge from the evidence of the large amount of material obtained from the Upper Aquitanian beds of the Bugti hills, and we therefore consider that no useful purpose would be served by attempting to separate such specimens merely on the ground of a slight difference in size.

Our collection contains two fragments of mandibular rami each containing a single perfect premolar. One fragment is figured in Pl. 2, fig. 7, Pl. 3, fig. 6. One may conjecture that the larger of these two premolars is pm_3, both from the fact that it does not possess the inner ridge entire from the summit of the main cusp, as is the case in pm_4, but only a small fold branching off from near the base of the posterior ridge, and from the fact that the roots of a larger premolar tooth are visible in this fragment behind the perfect tooth, as well as because the perfect tooth in the other fragment is smaller than the one just mentioned and shows even less trace of an inner fold, while in front of it there appears to be the alveolus of another premolar. If our reasoning is sound the four teeth of which traces are present are the four premolars, and in that case we may deduce the important conclusion that the premolars are all in contact with one another and that no diastema is present. In front of the smaller fragment that portion of the bone which is visible beneath the hard resistant matrix, which conceals most of it from view, seems to us to suggest the conformation of a canine alveolus. If this is so there is only a slight diastema between the canine and the premolars. We may, therefore, infer that the constitution of the premolar portion of this mandible is altogether different from that of the European Oligocene species of *Anthracotherium*, though possibly not different from that of the Upper Eocene species *A. dalmatinum*. Beneath the assumed pm_3 there is a curve at the base of the fragment which suggests the presence of a downward process similar to what is often found in a corresponding position in the European species of *Anthracotherium*. A foramen, probably the mental foramen, is visible beneath the anterior portion of this tooth.

Pm_3 resembles very closely the corresponding tooth in the type mandible of *Anthracohyus chœroides*, except that the anterior cingular cusp is rather more pronounced. No difference is noticeable between pm_2 in the two mandibles.

It is difficult to feel certain as to the place to which these two fragments should be assigned, but assuming that they belong to *Anthracohyus* rather than to *Anthracotherium*, their size impels us to refer them provisionally to the species *Anthracohyus rubricæ*, although they appear to be a little larger than would accord with the individuals to which either the upper molars or the lower teeth just described belonged.

ANTHRACOHYUS PALUSTRIS n. sp.

(Pl. 3, figs. 7—9.)

The types of this species are two well worn upper molars (G. S. I. Nos. B. 606, K. 18-847), which are distinguished by their size from all the other Pondaung species. One of these is figured in Pl. 3, fig. 7. The bunodonty of the outer cones, the absence of a parastyle and the feeble mesostyle and metastyle, link them to *Anthracohyus chœroides*. Besides their superiority in size, they differ from the other anthracotheroid upper molars of the Pondaung sandstones by the protuberance of the base of the tooth on the internal and posterior sides. The hypocone and, to a smaller extent the protocone, rise very suddenly from this swollen base, which thus produces somewhat the effect of a cingular shelf, in continuation of the posterior true cingulum, which at the same time is stronger and extends further to the inside than in the other Pondaung species.

3rd upper premolar.—There is so little difference except in size between this tooth (G. S. I. No. B. 608: Pl. 3, fig. 8) and the corresponding tooth described under the head of *Anthracohyus chœroides*, that hardly anything need be added to that description. The cingulum between the posterior and internal cusps is, however, stronger in this than in the other, so that the outline of this corner of the tooth is convex instead of being concave.

Last lower molar.—The specimen of an anthracotheroid m_3 (G. S. I. No. B. 607) figured in Plate 3, fig. 9 can, on account of its size, be only referred to the present species. A protuberance, somewhat similar to that noticed in the case of the upper molars, can here be observed on the outer base of this tooth. Its breadth index exceeds that of any of the other species except *Anthracotherium crassum*, and the tooth is also more brachyodont. The shape of the talon bears less resemblance to the usual anthracotheroid loop, than either in *A. chœroides* or any of the other Pondaung species. This is due to the fact that the two hinder cusps are stronger and more distinctly separate from one another, and also that the crests connecting them to the 2nd barrel are higher and run side by side, leaving no space for the usual cavity.

ANTHRACOTHERIUM PANGAN n. sp.

(Pl. 4, figs. 1—3.)

The upper molars of this species are almost precisely of the same size as those of *Anthracohyus rubricæ*, but are distinguished by the presence of a distinct parastyle. Thus the outer cones are decidedly more selenodont. All the outer styles are feebler than in any of the hitherto described species of *Anthracotherium*, but in the absence of knowledge as to any more important distinction than this, it does not seem feasible to separate it generically from these. Should further material give evidence of a canine and incisor region differing from *Anthracotherium* more than we anticipate at present, it might be necessary to consider the advisability of separating it from the latter genus. Until then we think it better to leave this species in the genus *Anthracotherium*, while recognizing that its upper molars display a tendency to approach those of *Anthracohyus*—a tendency which we fully expect will be borne out by the front portion of the jaw and dentition, when the latter shall be discovered. It is considerably larger than *Anthracotherium dalmatinum* the earliest species of the genus known up till now, but the lesser development of the outer styles in the present species indicates a more primitive condition. The last lower molar figured in Plate 4, fig. 2, is provisionally referred to this species with which it agrees in size. No distinction can be drawn between it and the m_3 referred to *A. rubricæ* except a somewhat greater breadth index, especially noticeable in the talon.

3rd upper premolar.—The specimen (G. S. I. No. B. 618) figured in Plate 4, fig. 3, though much worn by abrasion during the animal's life and badly weathered subsequently, is of interest because it displays characters which we associate with the corresponding tooth of *Anthracotherium*, and which distinguish it from pm^3 of *Anthracohyus*. The ridges in front of, and behind, the main cusp are not parallel to the antero-posterior axis, but run in a direction oblique to it. In the antero-external angle of the tooth, there is a strong bulge in the outline of the outer wall quite distinct from the tapering anterior portion in pm^3 of *Anthracohyus*, while in the postero-internal angle, the side of the main cusp slopes much less steeply to the base between the inner cusp and the hinder ridge. In consequence of these features the outline instead of being subtriangular as in *Anthracohyus* tends to be trapezoidal as in *Anthracotherium*. This

tooth is provisionally referred to the species *A. pangan* with which it seems to agree more nearly in point of size than with *A. crassum*.

ANTHRACOTHERIUM CRASSUM n. sp.

(Pl. 4, figs. 4—5 and Pl. 5, fig. 1.)

The differences assumed to be of generic value, separating this species from the various species of *Anthracohyus*, are even less than in the case of *A. pangan*, since there is only a feeble parastyle and a weak mesostyle. Specifically it can easily be distinguished from all the other anthracotheroid species of the Pondaung sandstones by the extreme lowness of the tooth crowns. Moreover, although the base of the tooth is very broad, the cusps both on the outside as well as on the inside of the tooth slope towards the centre of the tooth at so great an angle, measured from the vertical, that the cusps are closer together in proportion than in the other species. The protoconule is also lower. There is no trace of an internal cingulum. The dimensions of this species would seem to be rather less than those of *Anthracohyus rubricæ*.

4th upper premolar.—The specimen (G. S. I. No. B. 616), figured in Plate 4, fig. 4, probably belongs to the same individual as the two upper molars. Compared with the corresponding tooth of *A. rubricæ*, the most striking difference consists in the much more selenodont condition of the outer cusp owing to the elevation of the cingulum both in front of and behind the main cusp into moderately prominent styles. Further the stronger cingulum at the postero-internal angle gives the tooth a squarer and less triangular outline than in pm^4 of *A. rubricæ*. Finally a very distinct anterior median cusp is present. In all these features the tooth is closer to pm^4 of *Anthracotherium* than to *Anthracohyus*.

Mandible.—The reference of this mandible (G. S. I. No. B. 617), figured in Plate 4, fig. 5, to the species *A. crassum* is, perhaps, more certain than any of the other provisional references of mandibles made in the present paper. The large breadth index, the high degree of brachyodonty and the closer approximation of the cusps correspond entirely to the similar features noticed in the case of the upper molars, and leave no doubt in our minds as to the correctness of the reference.

The ramus is rather stout. The molars do not differ in any essential points of structure from those of the other Pondaung

species. The very much abbreviated talon is, however, worthy of mention and offers a very clear means of distinguishing m_3 in the species *A. crassum.*

Last lower premolar.—If we compare this tooth with the pm_4 of *Anthracohyus chœroides* we shall be struck by its much stumpier, less elongated, appearance. Instead of tapering in front there is a distinct tendency to squareness, so that the tooth has almost a trapezoidal outline. The anterior cusp is situated rather to the inside of the antero-posterior axis, so as to give the wall of the tooth between it and the inner posterior ridge a concave instead of a convex outline, at all events near the base of the crown. In all these features we see a distinct approximation to the structure of pm_4 in the European species of *Anthracotherium.* This tooth is not unlike pm_4 of *Anthracotherium bugtiense* except that in the latter the anterior cusp does not lie internal to the antero-posterior axis and consequently there is no concavity in its outline.

ANTHRACOKERYX BIRMANICUS n. gen., n. sp.

(Pl. 5, figs. 2—5.)

The type of this genus and species is a right maxilla (G. S. I. No. B. 621; Pl. 5, fig. 2) containing the three molars and the two hinder premolars. The molars resemble those of *Microbunodon* in structure, having fairly pronounced outer styles and thus a greater tendency to selenodonty than in the case of *Anthracohyus.* From the latter genus, as from *Anthracotherium,* they differ also by the absence of a protostyle. Pm^4 seems to differ in no essential respect from that of *Microbunodon*; pm^3 has, however, an entirely different shape to the corresponding tooth in that genus. Instead of being almost equilaterally triangular with a broad cingulum on two of these sides and no prominent inner cusp, it is elongated and in outline is almost identical with pm^3 of *Anthracohyus.* The wear of the tooth in its hinder portion prevents us from comparing it in greater detail. *Rhagatherium* and *Haplobunodon* resemble *Microbunodon* in the structure of pm^3.

Upper milk molars.—The specimen (G. S. I. No. B. 624) figured in Plate 5, fig. 4, containing the last two left milk molars, may reasonably be referred to this species. Mm^4 differs in no respect from the permanent molars which have just been described, and

might be that of a *Microbunodon*. Mm³ differs from that of *Anthracotherium* and *Microbunodon* by the much greater elongation of the front part of the tooth and by the absence, or at all events feeble development, of the mesostyle.

In front of the two posterior cusps are three cusps which form a single diagonal line running from the postero-external cusp to the anterior end of the tooth, which tapers almost to a point. Of these three cusps the middle one is the tallest, the posterior one is partially united to the main one, and the front one, though well isolated from the others, is low. On the inside of the tooth a cingulum runs from the front end into the V-shaped valley adjoining the posterior pair of cusps. *Rhagatherium* and *Haplobunodon* differ by having only two anterior cusps, by the diminution in breadth of the tooth in front of the posterior pair of cusps, and the consequent restriction of the V-shaped valley mentioned, and by the cusps being generally more bunodont than in the one before us.

Lower molars.—The only lower molar which might from its size belong to the upper molars of *Anthracokeryx birmanicum* is the fragment (G. S. I. No. B. 623; Pl. 5, fig. 5) containing the hinder portion of m_3. The most noteworthy feature about the talon of this tooth is the absence of any distinct double cusp. It agrees in this respect with the various last lower molars from the Lower Siwaliks referred to the species *Anthracotherium* (*Microbunodon*) *silistrense* Pentland, as well as with *Anthracotherium* (*Microbunodon*) *mus* Pilg. The European species of *Microbunodon*, however, appear to have two cusps in the talon.

ANTHRACOKERYX TENUIS n. sp.

(Pl. 5, figs. 6—8.)

We place here a collection of upper and lower molars (G. S. I. Nos. B. 625 and B. 626; Pl. 5, figs. 6 and 7) which are much smaller than any hitherto referred to from the Pondaung sandstones, and which one of us collected from a single spot. They are only about one-third of the size of *Anthracokeryx birmanicus*, but differ from the upper and lower molars of that species in no essential points of structure, differing from *Anthracohyus* by the stronger outer styles and by the absence of a protostyle. No specimen of m_3 is included in the collection from this locality.

From another locality comes another fragment of a right mandibular ramus (G. S. I. B. 627; Pl. 5, fig. 8) with m_2 and m_3. This is slightly larger than the molars last described, but this difference in size does not seem beyond the limits of individual variation in the Anthracotheroids. The points in which this specimen differs from the fragment (G. S. I. No. B. 623) described under the head of *Anthracohyus birmanicus* are the following:—the ramus is very much shallower; there is no swelling beneath m_3 accompanied nearer the base by a marked groove; the double cusp in the talon of m_3 is quite clearly indicated.

Measurements of Anthracotheriidæ (in millimetres).

MANDIBLE.		Anthracohyus chœroides.	Anthracohyus rubricæ.			Anthracohyus palustris.	Anthracotherium pangan.	Anthracotherium crassum.	Anthracokeryx tenuis.	
Register numbers, G. S. I.		B. 605	B. 613	B. 612	B. 614	B. 607	B. 620	B. 617	B. 627	B. 626
M_3	Length	29·8	38·1	..	..	53·1	47·2	36·4	17·4	..
	Breadth	15·8	20·5	..	..	29·2	25·4	22·8	8·1	..
	Breadth index	53·0	53·8	..	..	54·9	53·8	62·6	..	..
M_2	Length	17·4	..	23·7	..	..	..	26·2	12·2	..
	Breadth	13·3	..	17·4	..	..	..	[1] 21·2	7·3	..
	Breadth index	70·4	..	..	..	..	..	80·9	..	..
M_1	Length	13·4	..	16·7	..	..	..	18·5	..	9·7
	Breadth	9·5	..	11·8	..	..	..	..	..	5·6
Pm_4	Length	13·0	..	..	..	..	..	19·4	..	..
	Breadth	7·9	..	10·8	..	..	..	12·6	..	..
Pm_3	Length	14·9	..	..	20·9	..	..	..	..	..
	Breadth	5·8	..	..	10·4	..	..	..	..	..
Pm_2	Length	12·8	..	..	..	..	..	..	..	..
	Breadth	4·5	..	..	..	..	..	..	..	..
Pm_1	Length	8·2	..	..	..	..	..	..	..	..
	Breadth	4·0	..	..	..	..	..	..	..	..
C	Length	9·3	..	..	..	..	..	..	..	..
	Breadth	4·6	..	..	..	..	..	..	..	..
$\frac{\text{Thickness of mandible}}{\text{Length of } m_3}$		$\frac{21·3}{17·4}$	..	..	..	..	..	$\frac{33·7}{26·2}$	..	..
Index		122·4	..	..	..	..	..	128·6	..	..

Measurements of Anthracotheriidæ (in millimetres).

MAXILLA.		Anthracohyus chœroides.		Anthracohyus rubricæ.			Anthracohyus palustris.			Anthracotherium pangan.		Anthracotherium crassum.		Anthracokeryx birmanicus.		
Register numbers, G. S. I.		B. 603	B. 604	B. 609	B. 610	B. 611	B. 606	K. 18/847	B. 608	B. 619	B. 618	B. 615	B. 616	B. 621	B. 624	B. 625
M³	Length	20·9	..	31·9	..	..	39·7	..	..	34·1	..	26·9	..	16·2	..	..
	Breadth	26·6	..	34·3	..	..	(?)	..	..	36·5	..	32·4	..	19·0	..	..
	Breadth index	127·2	..	107·5	..	..	..	..	..	107·0	..	120·4	..	117·2	..	..
M²	Length	..	..	..	25·3	..	..	33·8	..	27·2	..	21·3	..	14·8	..	9·9
	Breadth	..	..	..	30·7	..	..	40·9	..	27·4	..	24·4	..	16·8	..	9·9
	Breadth index	..	..	..	121·3	..	..	121·0	..	100·7	..	114·5	..	118·5	..	100·0
M¹	Length	..	..	..	..	..	..	..	..	..	..	..	..	12·5	..	7·4
	Breadth	..	..	..	..	..	..	..	..	..	..	..	..	14·3	..	7·8
	Breadth index	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Pm⁴	Length	..	..	..	..	14·8	..	..	..	..	..	..	15·8	9·2	..	..
	Breadth	..	..	..	..	18·4	..	..	..	..	..	..	19·8	12·0	..	..
	Breadth index			..	..	..	..	..	..	..	..	..	..	..	..	..
Pm³	Length		15·4	..	..	..	..	..	24·5	..	24·1	..	..	13·4	..	..
	Breadth	..	11·7	..	..	..	..	..	20·3	..	19·7	..	..	9·9	..	..
	Breadth index	..	75·97	..	..	..	..	..	82·8	..	..	..	..	73·8	..	..
Mm⁴	Length	..	..	..	..	..	..	..	..	..	..	..	..	..	11·6	..
	Breadth	..	..	..	..	..	..	..	..	..	..	..	..	..	11·9	..
Mm³	Length	..	..	..	..	..	..	..	..	..	..	..	..	..	13·9	..
	Breadth	..	..	..	..	..	..	..	..	..	..	..	..	..	8·8	..

Amynodontidæ.

METAMYNODON (?) BIRMANICUS n. sp.

(Pl. 6, figs. 1—13.)

The material upon which this species is founded is exceedingly fragmentary; moreover positive proof is lacking that the association of the individual fragments here described is real and not due merely to coincidence, although as regards some of them there is strong evidence that such is really the case. Consequently we do not consider that either on the one hand the establishment of a new genus is advisable, or that on the other hand an unqualified reference to the genus *Metamynodon* is justified in view of the undoubted differences between the dentition of the Burmese species and that of *Metamynodon planifrons*. It is hoped that subsequent collections will soon settle the question definitely, and completely elucidate the structure of this interesting form.

The most perfect of the specimens which have been obtained from Myaing is the right mandibular ramus (G. S. I. No. C. 316) figured in Pl. 6, fig. 1, with which there can be practically no doubt that the canine (G. S. I. No. C. 317), figured in Pl. 6, fig. 2, is correctly associated, as it was picked up in the same spot by one of us and its state of mineralization is additional evidence that it belonged to the same individual as the ramus. This is therefore taken as the type of the species.

The fragment contains five teeth, but is fractured on both sides of the dental series. The entire depth of the ramus is shown in the middle, although the base of the jaw is missing both in front of, as well as behind, this portion. The teeth are well worn, the foremost one least so, while the third from the front is most worn, the amount of wear diminishing as we go farther backward in the jaw. There is also no zone of contact behind the last tooth, so that it is clear that the last three teeth are molars and the two foremost ones are pm_3 and pm_4. The absence of any zone of wear on the anterior wall of pm_3, as well as of any alveolus in front of the latter tooth, makes it tolerably certain that both pm_1 and pm_2 were missing.

As will be seen from the measurements on page 71, all the teeth are laterally compressed, while the premolar series is considerably reduced as compared with the molar series, the united length of the two premolars being no more than two-thirds of the length of m_3.

Molars.—These are of a roughly rectilinear outline. They are composed of two crescents, the sutures between which externally have united to such a degree as to produce a practically continuous external wall to the tooth. This wall in m_1 and m_2 is regularly convex, but in m_3 forms a slight re-entrant curve. A very distinct cingulum is present on the external wall of m_3, but there does not appear to be any trace of this in m_1 or m_2. The surface of the molars is so worn that it is not possible to be certain that the anterior of the two crescents was the smaller of the two, although this was probably the case. At the antero-internal corner of m_3, a distinct cingulum is present, but this is absent from any other part of m_3, nor is such a cingulum visible in a corresponding position in m_1 or m_2.

Premolars.—These are composed of double crescents of which the posterior one is the larger; moreover the front arm of the anterior crescent bends round but slightly, though more so in pm_4 than in pm_3. Consequently the outline of the latter tooth is triangular. The suture between the two crescents on the external wall is visible far more plainly in the premolars than in the molars, being shown as a very distinct furrow separating two convex surfaces.

Lower Canine.—This is a triangular tooth with an anterior ridge and two posterior ridges. The posterior surface of the tooth is slightly hollowed between the two hinder ridges, and laterally there is a faint groove visible both on the root as well as on the tooth. This is more marked on one side than on the other. On one side of the tooth the presence of a slight cingulum can be traced.

The cusp summit of the specimen has been entirely removed by abrasion against an upper tooth. As the zone of wear forms an oblique surface sloping backward at an angle of about 45° from the present summit of the tooth, it is likely that the wear has been produced by an upper canine biting behind the lower canine, especially as the anterior ridge of this tooth appears to have had its sharp edge worn away by contact with another upper tooth which must have been an incisor. The position of the alveolar edge of the enamel as well as the curvature of the root, show that this tooth must have occupied an almost or quite erect position in the jaw. This constitutes an important difference from *Metamynodon planifrons* and shows that in our species the lower canine had as yet hardly begun to assume the procumbent position of later forms, which was destined in time to cause the atrophy of the upper canine through

disuse and the hypertrophy of the upper incisor through the lower canine biting against it.

Comparisons.—The lateral compression of the teeth in this mandible, the obliteration of the external sutures of the crescents in the molars, and the small size of the premolars compared with the molars, points to an affinity with two known genera only, *Metamynodon* and *Cadurcotherium.* In size it agrees with *Cadurcotherium minus* of the Quercy Phosphorites, while it is smaller than the other species of *Cadurcotherium, C. cayluxi, C. nouleti* and *C. indicum.* The two latter species attain prodigious dimensions and characterize the Stampian of Europe and the Aquitanian of India respectively. *Metamynodon planifrons* very considerably exceeds the present species in size. The Burmese species appears to be nearer to *Metamynodon* than to *Cadurcotherium* in the smaller lateral compression of the teeth. This is most noticeable in the last molar, the posterior crescent of which in *Cadurcotherium* bends round only slightly to the inside, being extended backward, and so causing the tooth to have a subtriangular outline, instead of the rectilinear one of *Metamynodon.* The shape of pm_3 in our species on the other hand is more like the corresponding tooth in *Cadurcotherium* than in *Metamynodon.* In the latter genus the anterior crescent is indistinct, and in any case its anterior arm does not curve round internally in the least. In *Cadurcotherium* the anterior crescent is distinct. *Metamynodon* shows no trace of an external cingulum, as present in m_3 of our species. *Cadurcotherium indicum,* on the other hand, has an indication of such a structure, though not nearly as pronounced as in the Burmese species.

The lower canine corresponds in general shape and condition of wear with the corresponding tooth in both *Metamynodon* and *Cadurcotherium,* but is very much smaller than in either of those genera. As far as we can judge, the teeth are much less hypsodont than those of *Metamynodon* and *Cadurcotherium,* while cement if it ever existed has at all events left no trace of its former presence on any of the teeth. In conclusion, while this mandible affords us ample evidence for the existence of a species of Amynodont distinct from any previously known, exhibiting a much less degree of specialization than any described species of *Metamynodon* or *Cadurcotherium,* yet there is nothing which would enable us to decide whether this species was ancestral to both of the genera mentioned or to one of them only, and if the latter to which. We feel that in these circumstances we

must be guided by the indirect indications afforded by the fragmentary upper teeth about to be described.

The most important of these remains is a collection of exceedingly broken and incomplete teeth found by one of us in a single spot and with very little doubt representing the much weathered and disunited fragments of what were once the palatal and premaxillary portions of an amynodont skull. They include the internal portions of two right upper premolars (G. S. I. Nos. C. 318, C. 319; Pl. 6, figs. 3, 4), fragments of the ectoloph of three right upper molars, which, judging by the different stage of wear reached in each, must represent m^1, m^2 and m^3 (see Pl. 6, fig. 8), an upper canine (G. S. I. No. C. 320), and portions of four incisors including G. S. I. No. C. 322 (Pl. 6, fig. 7), representing three distinct types and therefore proving apparently the presence of three upper incisors. The presence of a persistent ectoloph in what we take to be m^3 (G. S. I. No. C. 323; Pl. 6, fig. 8) points, if we are correct in the assumption, to the jaw being that of an Amynodont. The metaloph is longer and less oblique than in the known species of *Cadurcotherium* and more resembles that of *Amynodon* or *Metamynodon*. Strong protoconal and paraconal ridges exist on the ectoloph of the molars. The premolars have a short metaloph, a small crista, and an internal cingulum, particularly well marked in the posterior portion of the tooth, but dying away against the base of the protoloph. This cingulum resembles that in the premolars of *Metamynodon* rather than in *Cadurcotherium*. In the latter genus it is stronger and continuous all along the internal base of the tooth.

The canine tooth (Pl. 6, fig. 5) has lost a portion of its postero-external side. It appears, however, to have had in cross section a transversely elliptical crown, when unworn, with a strong anterior ridge. Slightly internal to this ridge but in the anterior portion of the tooth there is a large oblique zone of wear. The great size of this tooth agrees well with all the known Amynodonts, as also does the antero-internal zone of wear caused by the lower canine.

From another locality various rhinocerotoid remains have been obtained which there are strong grounds for thinking are all amynodont, even though they may belong to a different species from the type mandible of *Metamynodon* (?) *birmanicus*. The first of these is a portion of a left maxilla containing two premolars, which have lost their ectoloph (G. S. I. No. C. 324; Pl. 6, fig. 9) and, in front of and in contact with the smaller of these two, a single root,

The premolars are identical both in size and structure with those which have just been described. It seems certain, therefore, that the species possessed four upper premolars, of which the foremost was one-rooted. *Cadurcotherium* appears to have but three upper premolars, so that our species agrees in this respect with *Metamynodon*.[1] A larger perfect premolar (G. S. I. No. C. 325; Pl. 6, fig. 10) from the same locality may possibly be pm^4 of this species. Here the protoloph and metaloph are united to form a central cavity, although the tooth is not in a very advanced stage of wear. The narrow isthmus separating the protoloph from the metaloph is visible, from which it appears that the metaloph was the more developed of the two. The cingulum is slightly more continuous internally than in the other premolars which we have described. The ectoloph has a strong paraconal fold, the parastyle being also marked.

Associated with the last two specimens are two lower molars (including G. S. I. No. C. 326; Pl. 6, fig. 11) which agree in structure perfectly with those in the type ramus except by being rather larger absolutely and less compressed laterally. These are obviously amynodont, and cannot, we think, be generically separated from the mandible even if there should prove to be sufficient justification for referring them to another species. With these also occurred a lower premolar practically unworn, which is slightly larger than the corresponding tooth in the type ramus, but is probably identical in structure. This specimen (G. S. I. No. C. 327) is figured in Pl. 6, fig. 12. It is triangular in outline with two crescents, of which the posterior one is the larger. The ectoloph is only slightly sinuous, with little trace of the suture between the crescents.

Another specimen associated with the above is an upper molar (G. S. I. No. C. 328; Pl. 6, fig. 13) probably m^2, which by its size and structure might belong to the same species as the mandible. The tooth is rhomboid in shape the longest of its four sides being the anterior and external, which are about equal in length. The posterior and internal sides are also equal in length and much shorter than the other two. A prominent paraconal fold is visible on the ectoloph and also a parastyle. A barely perceptible sinuousity

[1] Although the descriptions of *Metamynodon* state that it possesses only three upper premolars, yet the figure of the dentition in Osborn's Extinct Rhinoceroses, *Mem. Amer. Mus. Nat. Hist.* Vol. I, p. 91, fig. 10, shows a small pm^1. This is perhaps vestigial.

marks the metacone. Both the transverse crests are inclined backward, the central valley being narrower and more sinuous than in *Metamynodon planifrons* and more like either *Amynodon* or *Cadurcotherium*. There is no sign of a crista. There is no internal cingulum. A considerable post-fossette is produced by wear.

There remain the two one-rooted teeth figured in Pl. 6, figs. 6 and 7. These come from the same locality as the other remains last described. The one of these (G. S. I. No. B. 321) has an antero-posterior diameter of 14·5 mm. and a transverse diameter of 16 mm. The external wall of the tooth is strongly convex, forming nearly a semicircle.

The surface of the tooth has assumed, in consequence of wear, a crescent shape, the arms of the crescent being produced by the wear of an anterior and a posterior ridge. On the internal side of the tooth are two more ridges enclosing between them a small cavity and separated from each of the previously mentioned ridges by another cavity. Each of these cavities is bounded internally by a

Accepting all these specimens as representing a single genus, it is quite certain that we are dealing with a primitive member of the *Amynodontidæ*. The lateral compression of the lower teeth, their straight ectoloph and the reduction in length and in numbers of the premolar series (two lower premolars as against four in *Amynodon*), separate it, however, from *Amynodon* and clearly indicate that it is situated on a branch which had already begun to specialize in the direction of *Cadurcotherium* and *Metamynodon*. The presence of pm^1, the smaller size and probably erect position of the lower canine, the greater complication of pm_3 and the more brachyodont teeth are evidence that it has retained some of the primitive features of *Amynodon* which have disappeared in the Oligocene species *Metamynodon planifrons*. One may feel certain that these characters, which distinguish our species from *Metamynodon planifrons*,

undoubtedly existed in the ancestral type which gave rise to the latter, so that the differences, though possibly of generic value, are not inconsistent with an attribution of it to *Metamynodon* as a primitive species of that genus, particularly in view of the obvious difficulty of defining such a new genus positively from the material at our disposal.

The points in which it approaches *Cadurcotherium*, namely the rather more inclined ectoloph and the narrower median valley in the upper molars and the smaller space occupied by the premolars, would indicate that the hypothetical successor of the Burma species would be a marginal species of *Metamynodon* nearer to *Cadurcotherium* than the species *Metamynodon planifrons*.

Measurements in Millimetres of Metamynodon (?) birmanicus.

Mandible.	Type Nos.	C. 316 C. 317		C. 326	C. 327
Depth of jaw below m_2		69	..	..	..
Thickness of jaw below m_2		28	..	..	..
Antero-posterior diameter of molar and premolar series		141·7	..	..	..
M3	Length	47·0	45 (?)	..	..
	Breadth	20·5	22·0	..	..
M_2	Length	38·5	..	35·0	..
	Breadth	20·5	..	20·5	..
M1	Length	29·0	..	..	..
	Breadth	17·5	..	..	..
Pm4	Length	18·0	..	..	20·5
	Breadth	15·0	..	..	16·0
Pm3	Length	15·0	..	..	..
	Breadth	12·0	..	..	..
C.	Antero-posterior diameter	17·5	..	..	..
	Transverse diameter	12·5	..	..	..

Measurements in Millimetres of Metamynodon (?) birmanicus—contd.

Maxilla.		C. 328 C. 325	C. 319 C. 320	C. 324
M^2	Length	38·5	..	..
	Breadth	37·0	..	..
Pm^4	Length	21·0	..	..
	Breadth	32·0	..	..
Pm^3	Length	..	..	19(?)
	Breadth	..	..	29·5(?)
Pm^2	Length	..	15·	14·0(?)
	Breadth	..	..	..
C.	Max. diameter	..	21·0	..

Titanotheriidæ.

TELMATHERIUM (?) BIRMANICUM n. sp.

(Pl. 5, figs. 9—11.)

This species is represented by five fragments of upper molars, two of which are almost identical in shape and comprise the antero-internal quarter of two of the upper molars probably occupying successive positions in the maxilla and being either m^2 and m^3 or m^1 and m^2, two other portions of the wall of the external crescents, and another an isolated protocone. A sixth fragment consists only of the internal half of what we take to be the last upper premolar. Three of these pieces are figured in Plate 5, fig. 11.

It is obvious that these are not chalicotheroid; first because there is no trace of a protoconule which in the *Chalicotheriidæ* is always present between the protocone and the paracone, being invariably united to the latter by a transverse crest; secondly because the protocone in our specimens lies considerably more behind the level of the paracone than is the case in the *Chalicotheriidæ*; thirdly because in pm^4 there is a single large rounded and isolated inner cusp—the protocone, which is totally unconnected with the two main outer cusps, — a condition which never occurs in any Chalicotheroid.

In that family the protocone in the premolars is connected to the outer cusps either by a single or by a double crest. In addition to these specific differences, the general structure of the tooth is unlike that of any Chalicotheroid that is known to us.

On the other hand it approximates so nearly to that of many of the *Titanotheriidæ* that we have no hesitation in assigning these fragments to that family. A careful comparison with the various known species of the *Titanotheriidæ* convinces us that the Burmese fragments belong to a new species, but whether this is to be referred to one of the known genera of that family, or whether it belongs to a new genus, is a point which the material at our disposal is insufficient to enable us to determine. We shall therefore do no more than indicate its probable affinities, leaving a definite conclusion to the future, when we may hope that more abundant material may come to light.

One of the most crucial points which has presented itself to us for decision in connection with the material belonging to this species, is the position in the jaw of the tooth (G. S. I. No. C. 315) figured in Pl. 5, fig. 11. Although in some respects this specimen reminds us of the last upper molar in some of the Upper Eocene members of the *Palæosyopinæ*, yet its small size as compared with the two other specimens of the upper molars, militates against this view. Further the almost rectangular shape of the inner portion of the tooth, which alone is preserved to us, is inconsistent with the external widening which we must assume to have taken place in m^3 of this species. Again the faint V-ing of the line which connects the two external crescents points to these being more closely connected than is the case in the last upper molar of a Titanothere. On the other hand these features are such as the last upper premolar of that family would present, the only peculiarities being the rounded nature of the inner cone, and the highly developed cingula on the anterior and posterior margins of the fragment, dying away internally and apparently also on either side of the two main external cusps.

It is evident that this simple structure of pm^4 prohibits the possibility of this species being one of the *Titanotheriinæ* of the Oligocene, while on the other hand the increased development of the cingulum and the absence of an intermediate tubercle point to its representing one of the latest developmental stages of the Eocene sub-family of

the *Palæosyopinæ.* A similar indication is afforded by the fragmentary upper molars in which the protocone is rather lofty, and the only vestige of a protoconule is the presence of a minute row of beads, fringing the protocone between it and the paracone. These start from the prominent cingular protostyle and culminate in a more elevated portion some 13 mm. to the rear, diminishing again behind this point.

Attention may also be called to the presence in one of the specimens of a broad, gently rounded, median fold in the centre of the external paraconal wall of the tooth, although in the other specimen no such fold is visible. According to Earle such a median rib is characteristic of all the early Titanotheres, tending to vanish in the Upper Eocene and being entirely absent in the Oligocene sub-family of the *Titanotheriinæ*. In any case the external lobes are broad

E OF THE MAMMALIAN FAUNA.

orne in mind that the real evidence for ascribing fauna to the Upper Eocene is derived wholly from ...al relations of the beds containing it to the Yaw stage, which has yielded marine *Mollusca* and *Foraminifera* affording undoubted proof of correlation with one of the upper Eocene stages of Europe. This is fully discussed on page 44. Since we have at present no knowledge of any other mammalian fauna in Asia earlier than that of the Bugti Hills, which can hardly be placed into a lower stage than the upper Aquitanian, it is only possible to compare the Pondaung species with the older faunas of regions as remote as Europe or America, a comparison which can hardly be conceived as likely to yield very accurate results. At the same time such evidence of age as this fauna affords, is in entire support of that which the geology of the formation furnishes.

The anthracotheroid types, while including one which does not appear to differ essentially from that which we first meet as the species *Anthracotherium dalmatinum* of probable Auversian age, and which is represented by numerous other species in successive geological stages as far up as the Aquitanian, also include the bunodont

species referred to the new genus *Anthracohyus*, which undoubtedly indicate an earlier developmental stage than any hitherto recognized and one which probably gave rise to *Anthracotherium* proper. The species *Metamynodon birmanicus* though perhaps not the direct ancestor of the hitherto known species of *Metamynodon*, which are confined to the Oligocene, is certainly more primitive than the latter, possessing features which seem to represent a stage parallel to, but the equivalent of, the Eocene *Amynodon*. Finally the Pondaung Titanothere is clearly distinguished from the known Oligocene members of that family by the absence of a second internal cusp in the upper premolars, while on the other hand the absence of a protoconule in the upper molars, and certain other features noticed on pp. 73 and 74 point to its representing one of the later developmental stages of the Eocene Titanotheres, very similar to that which is represented by the upper Eocene species of *Telmatherium*.

EXPLANATION OF PLATES.

PLATE 1.

Geological Map of the country north of Myaing, Pakokku district; scale 1 inch = 1 mile.

PLATE 2.

FIGS. 1-4.—*Anthracohyus chœroides* n. gen. n. sp. All figures natural size.

FIG. 1.—Last left upper molar; nat. size; surface view.

FIG. 2.—Third right upper premolar; nat. size; surface view.

FIG. 3.—Right ramus of mandible, showing pm_4, m_1, m_2, m_3; external view.

FIG. 3*a*.—Isolated right lower pm_3, but belonging to above mandible; external view.

FIG. 3*b*.—Isolated right lower pm_2, belonging to above mandible; external view.

FIG. 3*c*.—Isolated right lower pm_1, belonging to above mandible; external view.

FIG. 3*d*.—Isolated right lower canine of above mandible; external view.

FIG. 3*e*.—Three incisors, probably right i_1 and left i_1 and i_2, of above mandible; external view.

FIG. 4.—Surface view of specimen shown in fig. 3.

FIG. 4*a*.—Surface view of specimen shown in fig. 3*a*.

FIG. 4*b*.—Surface view of specimen shown in fig. 3*b*.

FIG. 4*c*.—Surface view of specimen shown in fig. 3*c*.

FIG. 4*d*.—Surface view of specimen shown in fig. 3*d*.

FIG. 4*e*.—Surface view of specimen shown in fig. 3*e*.

FIGS. 5-7 (and Plate 2, figs. 1-6).—*Anthracohyus rubricæ*, n. sp.; all figures natural size.

FIG. 5.—Right upper molar (m^3), surface view.

FIG. 6.—Right upper molar (m^2), surface view.

FIG. 7.—Portion of left ramus of mandible, showing pm_3 and roots of pm_4 surface view.

PLATE 3.

FIGS. 1-6.—*Anthracohyus rubricæ*, n. sp. All figures natural size.

FIG. 1.—Right upper molar, m^3, external view (same specimen as is figured in Plate 2, fig. 5).

FIG. 2.—Right upper molar, m^2, external view (same specimen as is figured in Plate 2, fig. 6).

FIG. 3.—Fourth left upper premolar; surface view.

FIG. 4.—Left lower third molar; surface view.

FIG. 5.—Portion of left ramus of mandible, with m_2, m_1 and pm_4.

FIG. 6.—Portion of left ramus of mandible showing pm_3 and roots of pm_4; external view.

FIGS. 7-9.—*Anthracohyus palustris*, n. sp. All figures natural size.

FIG. 7.—Last left upper molar; surface view.

FIG. 8.—Right upper third premolar; surface view.

FIG. 9.—Last right lower molar; surface view.

PLATE 4.

FIGS. 1-3.—*Anthracotherium pangan*, n. sp. All figures natural size.

FIG. 1.—Upper left molars, m^2 and m^3; surface view.

FIG. 1*a*.—The same; external view.

FIG. 2.—Last left lower molar; surface view.

FIG. 3.—Third right upper premolar; surface view.

FIGS. 4-5.—*Anthracotherium crassum*, n. sp. All figures natural size.

FIG. 4.—Right upper fourth premolar; surface view.

FIG. 5.—Portion of right ramus of mandible showing m_3, m_2, m_1, and pm_4 surface view.

FIG. 5*a*.—The same; internal view.

PLATE 5.

FIG. 1.—*Anthracotherium crassum*, n. sp.; surface view of two left upper molars, m^2 and m^3; nat. size.

FIGS. 2-5.—*Anthracokeryx birmanicus*, n. gen. n. sp. All figures natural size.

FIG. 2.—Three right upper molars and two premolars; external view.

FIG. 2*a*.—Surface view of above specimen.

FIG. 3.—Another specimen; portion of maxilla with two upper right molars, m^2 and m^3; external view.

FIG. 3*a*.—Surface view of above specimen.

FIG. 4.—Third and fourth left upper milk molars; surface view.

FIG. 5.—Portion of mandible and of the last left lower molar.

FIGS. 6-8.—*Anthracokeryx tenuis*, n. sp. Figs. 6 and 7, magnified twice; fig. 8, natural size.

FIG. 6.—Portion of mandible with one permanent and one milk molar; surface view; mag. twice.

FIG. 7.—First and second upper molars; mag. twice.

FIG. 8.—Portion of the right mandibular ramus from a larger individual, showing the second and third molars.

FIGS. 9-11.—*Telmatherium* (?) *birmanicum*, n. sp. All figures natural size.

FIG. 9.—The antero-internal portion of a right upper molar; surface view.

FIG. 10.—External portion of an upper molar, showing the gently rounded median fold; external view.

FIG. 11.—Internal portion of last upper premolar; surface view.

PLATE 6.

FIGS. 1-13.—*Metamynodon* (?) *birmanicus*, n. sp.

FIGS. 1 and 1*a*, reduced to one-half natural size; the remainder, natural size.

FIG. 1.—Right mandibular ramus with three molars and two premolars; external view; reduced by $\frac{1}{2}$.

FIG. 1*a*.—The same; surface view; reduced by $\frac{1}{2}$.

FIG. 2.—Right lower canine; side view.

FIG. 2*a*.—The same; surface view.

FIGS. 3 and 4.—Internal portions of two right upper premolars.

FIG. 5.—Right upper canine; side view.

FIG. 5*a*.—The same; surface view.

FIG. 6.—An upper premolar, probably pm^1; side view.

FIG. 6*a*.—The same; surface view.

FIG. 7.—Probably an incisor; side view.

FIG. 7*a*.—The same; surface view.

FIG. 8.—Surface view of the posterior portion of a right upper molar, m^3.

FIG. 9.—Portions of two left upper premolars which have lost their ectolophs; surface view.

FIG. 10.—A right upper premolar, probably pm^4; surface view.

FIG. 11.—An isolated left lower molar; surface view.

FIG. 12.—An unworn lower left premolar, pm_4; surface view.

FIG. 13.—A left upper molar, probably m^2; surface view.

MISCELLANEOUS NOTES.

Chemical composition of the Red Marl of the Salt Range, Punjab.

In his Notes on the Salt Deposits of the Cis-Indus Salt Range (*Records*, 1914, Part 4) Dr. Christie had occasion once more to discuss the Red Marl (Salt marl) of the Salt series. I am satisfied that this series is of Cambrian or pre-Cambrian age and I certainly agree with Dr. Christie as to its sedimentary origin. There is one addition to be made regarding the latter statement. I happen to have made some years ago a quantitative analysis of Red Marl and the following is the result:—

SO_2	19. 64
SO_3	16. 45
Al_2O_3	7. 46
Fe_2O_3	2. 04
MgO	7. 32
CaO	21. 98
Loss on ignition	25. 46
TOTAL	100. 35

From this composition I calculate in round numbers the following proportions of minerals:—

Quartz (SiO_2)	9
Clay ($Al_2Si_2O_7+2H_2O$)	20
Gypsum ($CaSO_4+2H_2O$)	35
Hæmatite (Fe_2O_3)	2
Dolomite [(Ca, Mg) CO_3]	34
TOTAL	100

Calcium and magnesium carbonate are present in almost the exact proportion of pure dolomite $CaCO_3 + MgCO_3$. The amounts are 18·65 parts of the former and 15·30 of the latter. Flemming's early analysis gave the same minerals but only qualitatively. The proportion of hæmatite appears small considering the intense colouring of the soft rock.

When heated before the blowpipe the Red marl melts to a nearly colourless glass. It is impossible to imagine that the rock has ever been subjected to a high temperature through volcanic conditions. If it had been it would now be of the nature of a glass or a pumice, very different in appearance from its present state.

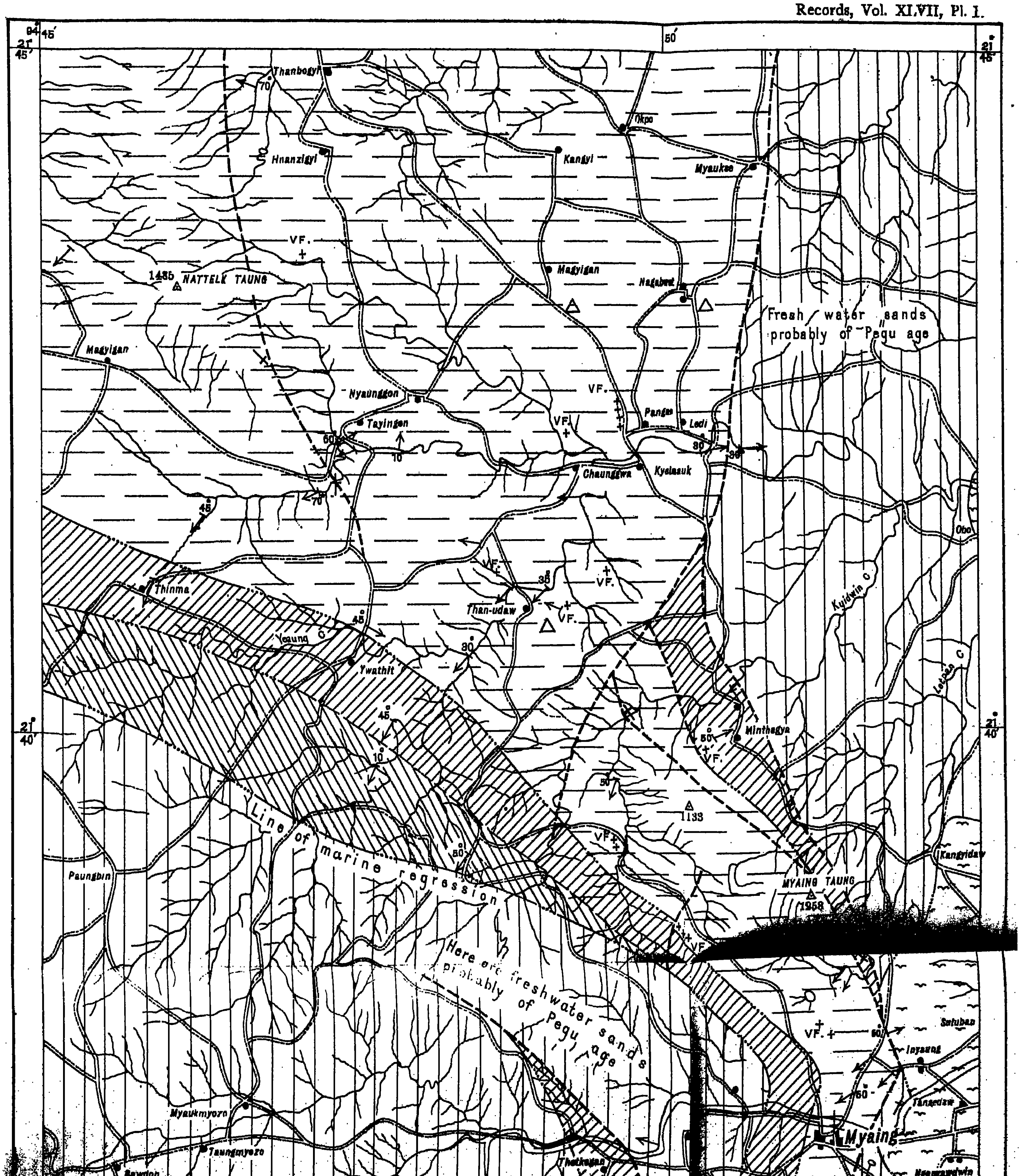
[H. WARTH.]

Corrective Note on the Age of the Tertiary of Java.

In a paper entitled " Notes on the Value of Nummulites as Zone Fossils " published in Vol. XLIV, p. 52 of these *Records*, I suggested that the fauna of Nanggoulan was Lutetian in age, and that the Preanguer limestone was Oligocene; both these formations having been placed in the Oligocene by Verbeek and Fennema in their work " Description geologique de Java et Madoura." Dr. Verbeek has now written to me pointing out that he had himself in 1908 revised his former estimate of the age of these beds. In a work entitled " Rapport sur les Moluques " p. 495, Dr. Verbeek places the Nanggoulan beds in the Upper Eocene, and retains the Preanguer limestone in the Oligocene. It appears therefore that my suggested revision of the Java Tertiaries, though sound enough, came a little late; the whole matter having been already discussed, and the necessary revision made, by Dr. Verbeek in the above-mentioned work, which was not known to me at the time of writing my paper.

[G. DEP. COTTER].

Records, Vol. XLVII, Pl. I.



GEOLOGICAL MAP OF COUNTRY NEAR MYAING, PAKOKKU DISTRICT,

by G. de P. Cotter.

INDEX

STAGE

ING SANDSTONES

DIP VERTICAL

GAS-POOL

FAULTS

+ V F = VERTEBRATE FOSSILS

BOUNDARIES BROKEN WHERE INTERPOLATED

Fig. 1

Fig. 2

Fig. 5

Fig. 6

Fig. 7

Fig. 3

Fig. 3 a

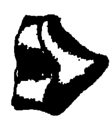


Fig. 3 b

Fig. 3 c

Fig. 3 d

Fig. 3 e

Fig. 4

Fig. 4 a

Fig. 4 b

Fig. 4 c

Fig. 4 d

Fig. 4 e

del. S. N. Guine. *G. S. I. Calcutta.*

ANTHRACOHYUS CHŒROIDES AND A. RUBRICÆ.


Fig. 1


Fig. 3


Fig. 5


Fig. 2


Fig. 4

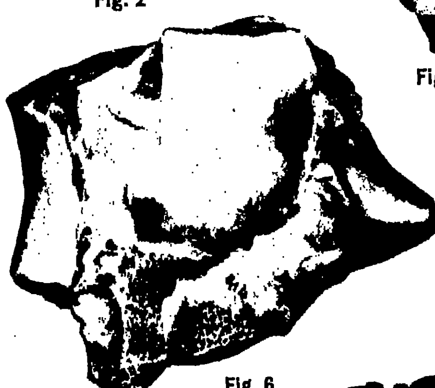


Fig. 6


Fig. 5a


Fig. 8


Fig. 7


Fig. 9

del. S. N. Guine. *G. S. I. Calcutta.*

ANTHRACOHYUS RUBRICÆ AND A. PALUSTRIS.

(All figures natural size.)

Fig. 1

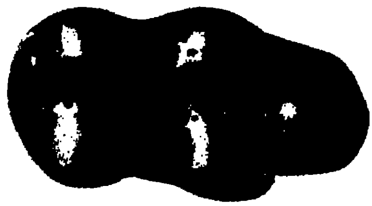


Fig. 2

Fig. 1 a

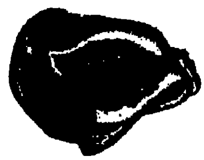


Fig. 3

Fig. 4

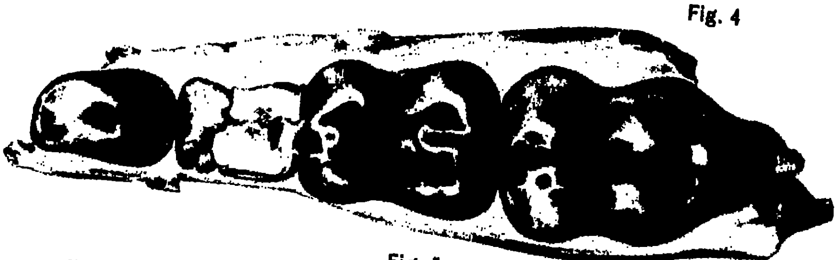


Fig. 5

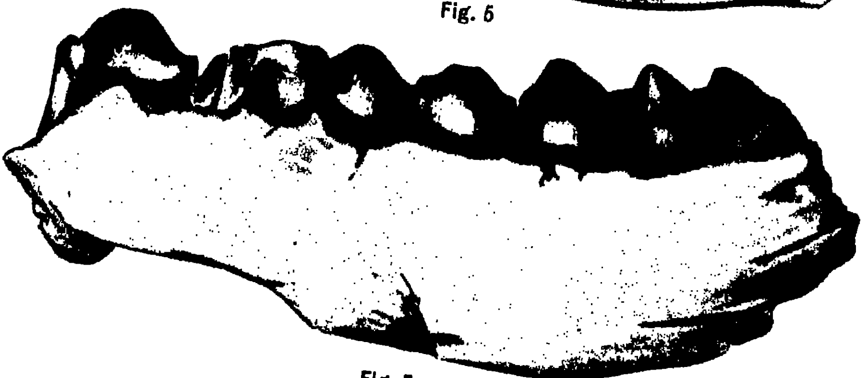


Fig. 5 a

del. S. N. Guine.

G. S. I. Calcutta.

ANTHRACOTHERIUM PANGAN; A. CRASSUM.

(All figures natural size.)

Fig. 1

Fig. 2

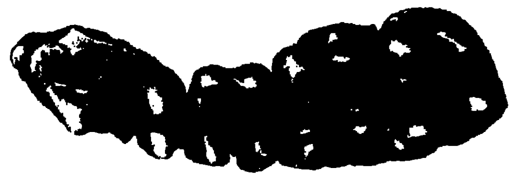


Fig. 2 a

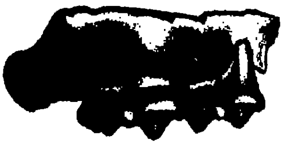


Fig. 3

Fig. 4

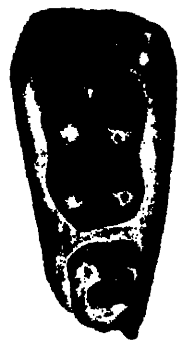


Fig. 6
× 2

Fig. 3 a

Fig. 5

Fig. 7
× 2

Fig. 8

Fig. 9

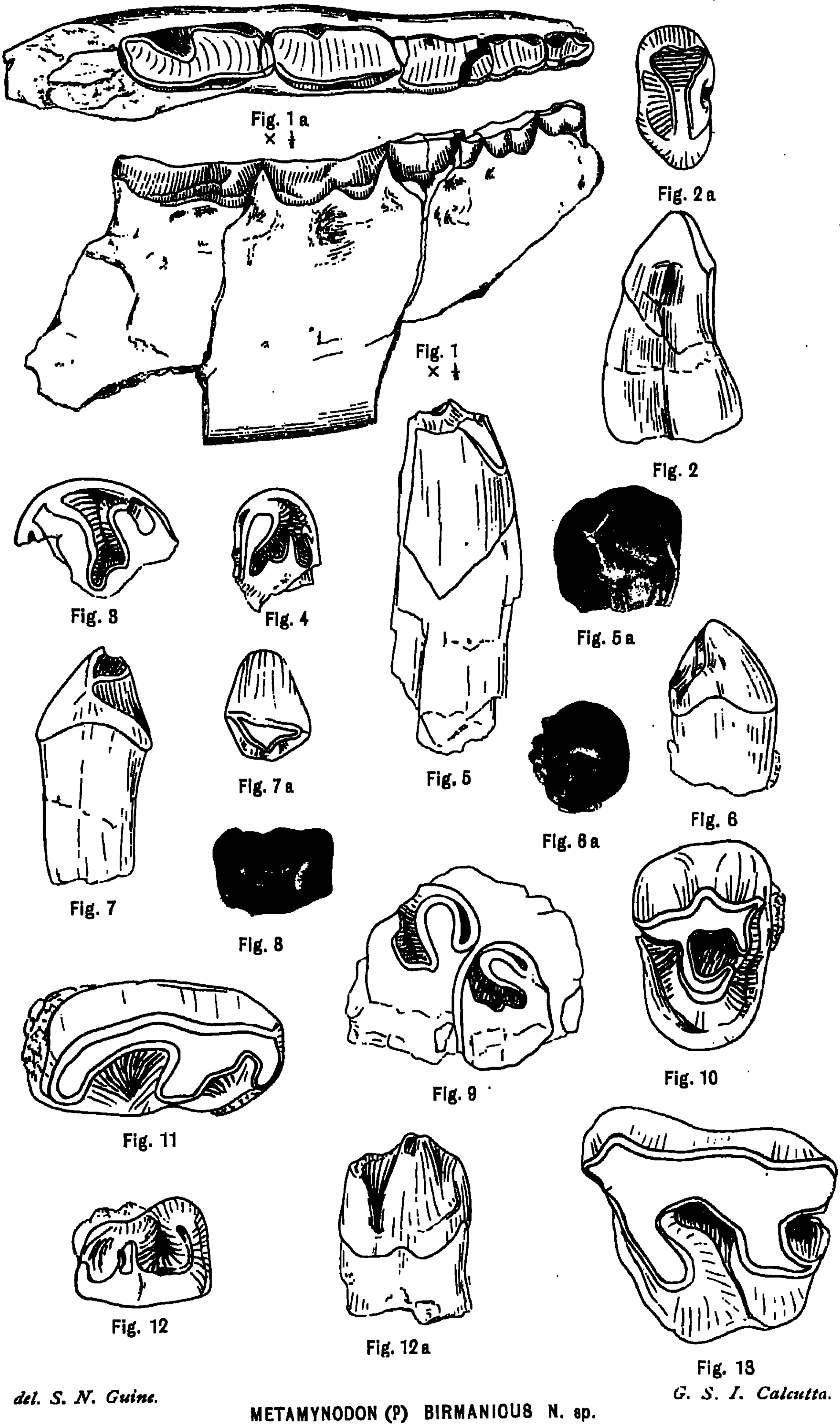
Fig. 10

Fig. 11

del. S. N. Guine. *G. S. I. Calcutta.*

ANTHRACOTHERIUM CRASSUM; ANTHRACOKERYX BIRMANICUS & A. TENUIS; TELMATHERIUM (?) BIRMANICUM.

(All figures except 6 & 7 natural size.)



del. S. N. Guine. *G. S. I. Calcutta.*

METAMYNODON (?) BIRMANICUS N. sp.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 2.] 1916. [June

THE DECCAN TRAP FLOWS OF LINGA, CHHINDWARA DISTRICT, CENTRAL PROVINCES. BY L. LEIGH FERMOR, D.SC., A.R.S.M., F.G.S., *Superintendent*, AND C. S. FOX, B.SC., M.I.M.E., F.G.S., *Assistant Superintendent, Geological Survey of India.* (With Plates 7 to 16.)

CONTENTS.

I.—INTRODUCTION.[1]

On commencing field work in the Chhindwara district of the Central Provinces in November 1911, I happened to place my first

[1] By L. L. Fermor.

camp near the large village of Linga, 6 miles south of Chhindwara town. Working amongst the basaltic lava flows of Deccan Trap age that surround this village, I soon discovered some indubitable dolerites, of much coarser grain than any of the basic lavas I had hitherto noticed elsewhere in this formation, examined in widely separated parts of India. Consequently, I commenced to map in detail a selected area round Linga with the object of determining whether the doleritic layers in the Deccan Trap formation are intrusive sills, as in the case of the dolerites of Skye, and as described by Dr. A. Harker in his 'Tertiary Igneous Rocks of Skye,' or whether they are extrusive lava flows, as seemed more probable judging by the scanty knowledge of the detailed natural history of this formation already in the possession of the Geological Survey of India.[1]

My collaborator in this paper, Mr. C. S. Fox, then recently appointed to the Geological Survey of India, joined me a few days later for his first field season; after working together for a while we separated, Mr. Fox mapping the northern and western portions of the area selected for survey, and I the southern and eastern portions. Careful work with the aneroid speedily showed that the traps were by no means horizontal; and, as a result of previous experience of the irregularly-eroded basement of older rocks on which the Deccan Trap flows have frequently been poured out, I was naturally inclined to interpret the irregularities in the Linga area as due to the adjustment of the trap flows themselves to the contours of the underlying Archæan surface. This led me into difficulties, and it was only on finding the palm-tree exposure near Chikhli that I recognised the probability of the existence of folding in the traps. Meanwhile Mr. Fox had already been successfully applying the idea of folding, and consequently I asked him to return to the area at the end of the season, when the crops were cut and most of the stream-beds dry, and finally to settle the question.

This he has done with great care and ability, establishing almost conclusively the existence of a parallel series of gentle anticlines and synclines striking W. by N. and E. by S., and pitching slightly to the E. by S. He has also disentangled from the changes of elevation resulting from these tectonic dips, those due to a sag in the flows, caused probably to a pre-trappean valley in the underlying granites

[1] A brief notice of this investigation has already been given in the General Report or 1911, *Records, G. S. I.*, XLII, p. 88, (1912).

running northwards from Linga towards Chhindwara. These dips, and other irregularities, are discussed at length in section V of this paper; but I have felt impelled to draw attention to them here, because the folding thus established by Mr. Fox is, perhaps, the most important fact about the Deccan Trap elicited by this investigation.

During the field season of 1912-13, I was able to follow the railway cuttings up the ghats at Jamunia, and to obtain evidence, which, added to that shown in road sections up the Amla Ghat on the Nagpur-Chhindwara road, renders it quite certain that the lava flows have been considerably disturbed since their consolidation.[1]

Furthermore, in April 1913, Mr. Fox and I met once again at Linga in order to clear up certain difficulties; we then obtained clear evidence of a fault traceable at intervals for 1½ miles, with a downward throw to the north of not less than 30 to 40 feet. This discovery has emboldened us to insert on the map smaller faults at two spots where the evidence is less clear.

We have arrived at the conclusion that the dolerites are not intrusive sills, but are true surface flows; flow 2 is particularly doleritic, but every flow tends to be doleritic towards the base.

In other parts of the district, dykes, both of basalt and of dolerite, pierce not only the older formations but also the Deccan Trap flows themselves; consequently, we do not deny the possible existence of intrusions following the bedding planes of the extrusive flows. Such a case has yet to be proved, however.

Whilst the credit of discovering and working out the folding belongs to Mr. Fox, I happened, by the accident of prior arrival, to discover the existence of the craterlets of Shikarpur, which we worked out together. Whilst we were unable at once to decide what interpretation to place upon these curious cavities—unique, I believe, in the Deccan Trap formation as at present known—we are now agreed that they most probably represent vents in the surface of a lava flow maintained for the escape of steam and gases, and sometimes perhaps, of lava, from still molten pools within the otherwise solidified flow.

Between each pair of flows (except 2 and 2A)—5 in number—existing in this area, there is an Intertrappean layer composed either (1) of 'green-earth,' or (2) of a silicified sediment (limestone) of fresh-water origin, often full of fresh-water fossils; but frequently

[1] Both these sections lie some miles to the south of the area here described.

(3) of both green-earth and sediment together. Green-earth is a very wide-spread material, occurring not only in these Intertrappean horizons, but also, frequently, within the flows themselves. It is probably the result of alteration of the basalts and dolerites, but its exact composition and mode of formation are being subjected to careful study by Mr. Fox, who hopes to publish later an account of his research. Any detailed discussion of its composition and origin is, therefore, omitted from this paper.

As has been noticed in the General Report of the Geological Survey of India for the year 1912 (*Records, G. S. I.*, XLIII, p. 32), the Infratrappean (Lameta) horizon, between the Archæan crystallines below and the Deccan Trap above, is of extremely complex character, consisting partly of true sediments, and partly of calcified and silicified representatives of the underlying crystallines. The discussion of this question, and consequently that of the alteration of the basal trap flow, is, however, beyond the scope of this paper, if for no other reason, because the area described contains no important exposure of these rocks; consequently no attempt is made here to describe and discuss the contact effects of the Chhindwara lavas on the underlying rocks.

In order that the map attached to this paper may be of the maximum value to the visitor to Chhindwara, it has been extended far enough northwards to include that town, which stands partly on granite and partly on Deccan Trap.

For purposes of compilation we have divided between us the work of writing the several sections of this paper, and I have attempted to combine the results into a homogeneous whole: but as my colleague is now serving with the Royal Engineers in France, he has had no opportunity of reading this paper as finally revised, so that it may conceivably contain statements that he might have wished to see modified.

II.—THE DISTRIBUTION OF THE FLOWS.

From the map (Plate 16) accompanying this paper it will be seen that we have recognised and mapped five flows of basaltic lava in the Linga area. They are numbered from the base upwards as flows 1, 2A, 2, 3, and 4, of which flow 2A has not been recognised in the northern parts of the area, where flow 2 rests directly on flow 1 without the intervention of flow 2A. Well-defined Inter-

trappean horizons, frequently carrying fresh-water fossils, separate from each other flows 1 and 2 (in the north), flows 1 and 2A (in the south), flows 2 and 3, and flows 3 and 4.

In the absence of any such intervening Intertrappean horizon it has been found impossible to separate flows 2 and 2A throughout the area mapped; where this separation has been effected, it has been based on a vesicular horizon at the top of flow 2A underlying the amygdaloidal base of flow 2, and giving rise to well-defined terraces of flow 2 resting on flow 2A.

The 'Lametas.'

The lowest flow rests almost directly on the Archæan gneisses and granites, there being as a rule a thin separating horizon of gritty impure limestone, the so-called 'Lameta limestone' of the Central Provinces. In some sections this limestone passes gradually downwards into the underlying gneisses and granites through a zone of partly silicified rock. Indeed, all our observations indicate that the limestone is a product of the replacement of the ancient crystalline rocks by calcium carbonate, derived probably from the overlying traps; it is possible that this process of alteration and replacement is still in active operation.

Good exposures of this calcified gneiss are to be seen in the Ramdoh, Bodri, and Kulbehra streams. The nearest exposure to Chhindwara is at the lime-kilns south of the railway station.

Flow 1.

Starting from Chhindwara town the lower boundary of flow 1 pursues a general southerly course as far as the Bodri stream, and then sweeps westward past Chandangaon and Khairwara to the edge of the present map. This, the lowest flow, appears to have abutted against a granitic ridge, situated to the south of Chandangaon, and accounting by its presence for an overlap of flow 2 directly on to the crystallines.

In addition to this northern fringe, numerous inliers of flow 1 are seen in the valley of the Kulbehra (see map) and the tributaries that join it from the west. One of these inliers occupies the bed of the Kulbehra continuously for several miles between Paunari and Bisapur.

Flow 2.

The second flow occupies, probably, a greater exposed area than flow 1, especially if considered in conjunction with flow 2A. Throughout the Linga tract flow 2 is separated from flow 1 by a remarkably persistent zone of

green-earth, which is from 2 to 12 feet thick and consists of a well-defined seam of green-earth passing upwards into the unaltered dolerite of flow 2.

Flow 2A.

To the north of Linga only one flow has been mapped between flows 1 and 3, but to the south there appear to be two well-defined flows in this position. The lower of these is distinguished as flow 2A, and, as will be seen from the map, occupies a considerable area along a belt of country stretching from Palamau and Buchnai to Bisapur in the south-east corner of the map.

Flow 3.

Flow 3 tends to occur as scattered outliers of elongated shape, with the longer axis oriented roughly east and west; but on the western border of the map—near Tekari and Koramau—this flow covers a considerable area.

Flow 4.

Flow 4, the topmost flow, is represented, in the area described, by only two outliers, one of them very small, capping Bandarjhiri Hill. It is, however, of frequent occurrence in the western parts of the Chhindwara district close to the Betul border.

Thickness of the flows.

On consulting the map, it is seen at once from a comparison of the distribution of the lava flows with the topography, that the surfaces separating the respective flows cannot be smooth planes. (Note particularly the distribution of flow 1 with reference to the river system). A certain degree of care has, therefore, to be exercised when using aneroid readings for calculating the thicknesses of the separate flows. The thickness of flow 1 is usually considerable, sometimes as much as 60 feet, and in places even greater. Flow 2A appears never to be much more than 45 feet thick; but flow 2 may be as much as 90 to 110 feet thick, *e.g.*, near the village of Murmari (assuming the absence of flow 2A at this point). Flow 3 averages 70 feet thick, whilst that portion of flow 4 still left on Bandarjhiri Hill is 30 feet thick. Thus we have in the Linga area 5 flows with an average thickness of about 60 feet, giving a total thickness of about 300 feet.

The same flows, with thicknesses of the same order of magnitude, cover the great tract of country stretching for many miles to the S. W. of Chhindwara town. But on the western border of the district, adjoining Betul, these flows possess an average thickness

of only 15 to 20 feet, and are overlain by higher and similarly thin flows; at the same time the fossiliferous horizons become rare or entirely absent.

In eastern Betul and southern Seoni, according to the evidence at present collected, by far the greater portion of the trap area is occupied by flows 1 to 4 of the Linga area, so that we must conclude that the Deccan Trap of the part of the Satpuras comprising eastern Betul, southern Chhindwara, and southern Seoni, is merely a thin crust, rarely more than 300 feet thick, and built up of the same flows as occur in the Linga area.[1]

Pre-trappean surface.

That the same flows should have spread over so large an area indicates in the first place that the lavas were extremely fluid. In the second place it probably indicates that there was a general direction of slope to the country, corresponding, of course, with the pre-trappean drainage system; for it seems improbable that the lavas, however fluid, would have flowed to such distances from their fissures of eruption unless they had been helped by at least a slight gradient. But the absence of inliers of Archæan rocks in the main Trap areas indicates that the relief of this pre-trappean surface must have been very low. The surface was in fact a peneplain, consisting of a slightly undulating plain with small hillocks and such slight depressions as are seen to-day in the crystalline country west of Chhindwara.

The pre-trappean and post-trappean drainage lines.

In the Linga area traces, of which the N.-S. sag noticed on page 110 is the most certain, of the pre-trappean river system seem to be discernible in the overlying flows. The partial reproduction by the lavas of the relief of the underlying surface may be due in part to the lavas having been less fluid than their wide extension suggests and in part to the differential effects of contraction as the lava cooled, the amount of vertical contraction being

[1] Much greater thicknesses of lava have, however, been found to exist in other parts of the Satpuras. Thus one of us (Fox) estimates the existence of 1,200 to 1,500 feet of lava in the high tracts to the north of Amarwara in the Chhindwara district (*Rec. G. S. I.*, XLV, p. 130, 1915); Mr. Vinayak Rao estimates the lavas on the western border of the Seoni district, adjoining the Amarwara tracts, to be 1,500 feet thick (*loc. cit.*, p. 134); Mr. Burton records the existence of 9 flows in the northern parts of the same district, with a total thickness of 775 feet (*loc. cit.*, pp. 30-131); whilst one of us (Fermor) and Mr. Hallowes have detected in the Mandla district 7 flows with the base not seen, of which the middle five flows totalled to 490 feet (*loc. cit.*, p. 128).

greatest where the depth of lava was greatest, namely over the buried valleys.[1]

The relief of the surface at the close of the eruption of the first flow would thus tend to be a faint copy of the pre-trappean relief, and denudation acting during a prolonged Intertrappean interval would accentuate this relief, the tendency being thus for a perpetuation of the pre-trappean drainage lines. The direction of banding of the gneisses underlying the traps of Linga is probably approximately E. to E. S. E., and consequently many of the valleys and ridges of the pre-trappean surface were probably aligned in this direction; but it so happens that a system of folding has been superposed on the traps (see section V) with its fold-axes parallel to the same direction: the more marked effects of the folding have, consequently, made it very difficult to detect traces of a pre-trappean drainage system with the same alignment. But this folding has not been able to obscure the traces of a probable N. and S. main drainage channel reflected in the sag in the traps referred to on page 110; the valley indicated by this sag is possibly the original cause, in the manner outlined above, of the present position of the main drainage channel of this area, namely, the Kulbehra, which pursues an average north and south course across the Deccan Trap area. The tributaries of the Kulbehra have, it will be seen, an average E. S. E. alignment, but this, perhaps, cannot be regarded as due to the preservation of the original direction of the tributaries

[1] This suggestion may be tested by a simple calculation. According to some experiments made by Bischof in 1841, if the volume of molten basalt be taken as unity, then the volume of the same cooled to glass is 0·9636, and when solidified in the crystalline condition is 0·8060 (see F. Zirkel, 'Lehrbuch der Petrographie,' I, p. 683, 2nd Edit., 1893): whilst according to experiments by R. Mallet, on the cubic contraction of blast-furnace slag near basalt in composition, carried out at Barrow in Cumberland, the total contraction between 3,080° F. and 53° F. is 67/1000, the volumes of molten and cooled product being therefore as 1 : ·933. The cooled product was half glassy (see 'Volcanic Energy,' *Phil. Trans.*, CLXIII, p. 201, 1873). Allowing for this we may deduce from Bischof's and Mallet's results a cubic contraction from the molten condition to the cooled solid of about 10 per cent. It is difficult to estimate what proportion of this contraction would appear as a vertical component, but allowing for the probability that all contraction of the lava while it was still plastic would tend to affect the vertical component, it seems probable that the total contraction in the vertical direction would be about 4 to 5 per cent. In the case where a valley 10 feet deep traversed the ground covered by a flow of basalt, the contraction of this extra thickness of basalt would, it is true, produce a maximum differential depression of the surface of only about 6 inches, whilst the depression at the surface caused by a valley 30 feet deep would be only some 15 to 18 inches deep at a maximum. These amounts are small, but they indicate the probability of a general tendency for the lava to slope towards the position of buried valleys, which would inevitably have its effect in determining the position of the new drainage lines.

of the pre-trappean main drainage channel, but as a function of the folding of the traps. It may be suggested, however, as a possibility that the post-trappean drainage system was established parallel to the original pre-trappean drainage before the folding of the traps, so that the folding merely had the effect of confirming the directions of drainage channels already in existence.

III.—THE MACROSCOPIC CHARACTERS OF THE FLOWS.

As already stated, there are four, and in parts five, lava flows of basaltic composition in the Linga area. These are :—

(1) The basal flow 1, which is often doleritic, sometimes with olivine :

(2) Flow 2, often doleritic and olivine-bearing, and separated in the southern parts of the area from the basal flow by a subsidiary flow 2A, which is mainly basaltic :

(3) Flow 3, with occasional olivine :

(4) The summit flow 4, which is of basaltic texture.

All the flows, whether basaltic or doleritic in texture, are clearly lava sheets poured out under sub-aërial conditions, there being no evidence of intrusive sills; for each flow has a vesicular surface, whilst the base of a flow is often also vesicular. In places, outside the area described, the basal portion of a flow is often zeolitic as well, the usual zeolite being heulandite. In general aspect the flows are all very similar, except that the colour of the rock appears to become slightly lighter as the higher flows are reached. This arouses the suspicion, which cannot be either confirmed or banished until the rocks have been analysed, that the percentage of silica increases slightly on passing from the lowest to the highest flow.

The alteration of the basal portions of the flows into green-earth to a thickness of 2 to 10 feet is a common feature, but it is particularly characteristic of flow 2, the base of which (or of flow 2A) has been converted into green-earth throughout the Linga tract.

That the Deccan Traps are rich in lime is indicated by the abundance of tufa found deposited in stream beds almost everywhere on this formation. Fig. 1 of Plate 7 shows a conglomerate of trap pebbles cemented by tufa. The formation of tufa however, is not always a case of simple deposition, but is sometimes effected at the expense of the lavas, patches and veinlets of tufa replacing

the basalts, especially the amygdaloidal forms. Such a case is illustrated in Plate 7, fig. 2.

A brief account of the macroscopic characters of each flow will now be given.

Flow 1.

Flow 1 rests on the calcified and silicified surface (the so-called Lameta) of the underlying crystalline gneisses, and at its base consists of a bedded doleritic type, much decomposed. In adjoining tracts the base is vesicular, the cavities being filled with calcite and heulandite (as near Deogarh). At other points (near Tigai and Mujawar) the base has been converted into green-earth; but frequently the basal trap is a porphyritic basalt, showing, where fresh, numerous felspar phenocrysts in a black minutely crystalline ground mass. Where decomposed this rock is soft and laminated with a lightish grey colour, the felspar phenocrysts being represented by soft opaque white patches.

Specimens taken from about the middle of the flow are distinctly doleritic, and sometimes coarse-grained and ophitic in structure, the fresh rock, as when obtained from newly-sunk wells, having a dark grey colour; but as usually obtained from ordinary exposures the rock shows a warm brown tint.

Higher in the flow geodes of quartz and chalcedony become common, and the texture of the rock more open.

Near the surface the rock is finer-grained and very vesicular, with a considerable quantity of macroscopically visible interstitial glass, which is undoubtedly a product of the original consolidation of the rock; it also contains abundant shot-like spherules of a black 'glass' which, from the ease with which it undergoes decomposition, increases the vesicular appearance of the rock.

This 'glass' is doubtless the same as the supposed chlorophæite, so characteristic of flow 3 (see page 94).

Throughout the flow phenocrysts of felspar are common. They are usually a few millimetres, but sometimes as much as a centimetre, long and tend to occur in aggregate stellate patches of the glomero-porphyritic type.

In this area flows 1 and 2A furnish the best exposures of surface phenomena of a lava flow. Good exposures of the surface of flow 1 are seen in the Kulbehra River opposite Shikarpur, and in the Karak Nadi opposite Khunajhir Kalan. The surface is vesicular, with numerous irregular geodes of quartz, agate, chalcedony, and onyx, and is traversed by numerous cooling cracks, which tend

to divide the lava into small polygonal portions a few inches across. In addition, the surface at Shikarpur is characterised by numerous circular hollows or *craterlets*, which are described in section VII of this paper. Another fine outcrop of the surface of flow 1 is seen in the Kulbehra at the point where it leaves the present map at its S. E. corner. In addition to showing the usual surface phenomena this exposure is traversed by numerous veinlets of chalcedony, on either side of which the basalt has been discoloured and somewhat decomposed, presumably by water or vapour at the time of the filling of the veins. The contrast between the decomposed and the unaltered trap has been accentuated by the differential erosion effected by the river.

At the palm-tree exposure in the Baradoi Nala near Chikhli, the surface of flow 1 is found to be much coarser-grained than usual; in fact it is a dolerite similar to the typical dolerites of this flow, except that it shows macroscopically visible patches of interstitial glass, and is slightly vesicular. Vesicular varieties of the dolerite are also seen in the exposure of flow 1 about 1 mile N. N. E. of Bisapur Kalan, and in the Baghora (or Ghogra) Nala near Paunari, whilst a non-vesicular variety of dolerite containing abundant patches of black glass is seen in the Kulbehra river at a point west by a little north of Bisapur Kalan.

Flow 2A.

Flow 2A is well exposed in many places along a belt of country extending in an E. S. E. direction from Buchnai and Pathranai to Bisapur Kalan. It is separated from flow 1 by a well-marked green-earth horizon, which is thicker than usual and very well exposed about a mile to the N. N. E. of Bisapur Kalan, and seems, as already stated, to represent the base of the flow in a state of decomposition. In many places the green-earth is underlain by a few feet of Intertrappean chert, *e.g.*, S. W. of Sarora, in the Palamau stream north of Sarora, and in the railway cutting west of Goreghat. Above the green-earth the flow is vesicular for a few feet and then passes through basalt into a rudely columnar doleritic basalt or fine-grained dolerite. This latter variety is well exposed as a small rock fall in a small nala about 1 mile E. N. E. of Lahgarua village, and in the right bank of the Kulbehra, just below the ford, where the track from Lahgarua to Bisapur Kalan crosses. The latter exposure shows the upward passage from basalt through doleritic rock to the surface basalt, overlain by the small outlier

of flow 2 indicated on the map. The surface of the flow is well exposed along the foot of the scarps of flow 2 stretching from Lahgarua to Bisapur Khurd, in the Baradoi Nala near Chikhli Kalan, on the south side of the Sarora Nala opposite Pathranai, and at the S. E. corner of Bhaurameta hill near Gadarwara. This surface is in all respects indistinguishable in physical characteristics from that of flow 1, except that craterlets have not been found.

The uppermost portion of the surface has often suffered decomposition due to percolating waters, with the production of a soft, earthy, vesicular, laminated rock, indistinguishable from the decomposed basal portions of the overlying flow 2.

Flow 2.

Flow 2, where it rests on flow 1 without the intervention of flow 2A, invariably overlies a thin stratum of fossiliferous chert. It commences as green-earth, which passes rapidly upwards into undecomposed, nodular, roughly columnar and flaggy dolerite (see Plates 8 and 9). This flaggy dolerite is quite characteristic of flow 2 in the northern parts of the Linga area, and is the particular portion of the flow that always reveals olivine to the microscope. The flaggy character is produced by intersecting curved joints of the cup and saucer type (see Plate 9, fig. 2). In texture this dolerite is very compact, of moderately fine grain, and without ophitic or porphyritic structures.

Above the flaggy zone, however, the dolerite is often exactly like that of flow 1, and passes up into open-textured doleritic basalt in which quartz geodes are abundant, many of the crystals being slightly amethystine. The surface is very similar to that of flow 1.

No flaggy dolerite has been observed south of Linga village, the upper vesicular horizon passing down into a doleritic basalt, which rests upon the additional flow 2A already described, instead of on flaggy dolerites.

From an examination of specimens of flow 2 collected in upward succession from the base it appears that where flaggy dolerite is found the flow cooled with sufficient slowness, perhaps because of greater thickness than elsewhere, to permit a small degree of differentiation in the lava, heavy porphyritic crystals of olivine sinking slowly in the magma and effecting a relative concentration of olivine in the flaggy basal portion.[1]

[1] *Cf.* R. A. Daly, *Journ. Geol.*, XVI, p. 401-420, (1908), and the case described by J. P. Iddings, of a sinking of augite phenocrysts in a 30-foot intrusive sheet of shoshonitic composition on Electric Peak, Yellowstone Park: Monograph 32, pt. 2, U. S. Geol. Surv. p. 82, (1899).

Flow 3.

Flow 3 is sometimes separated by a fossiliferous chert horizon from flow 2, and sometimes rests directly thereon, the base of flow 3 being either decomposed basalt or green-earth passing rapidly upwards into a fine-grained dark grey basalt. This rock is often beautifully columnar, as is well seen in the railway quarries about a mile N. and N. N. E. of Linga, close to the Kulbehra river.

The upper portions of flow 3 are geode-bearing and vesicular; whilst the surface of this flow exposed just to the north of Bandarjhiri Hill is the most vesicular of the surfaces that have been observed in the course of our mapping.

Amygdales of chlorophæite (?).

In places this basalt contains abundant shot-like spherules of glassy aspect averaging from $\frac{1}{8}$ to $\frac{1}{4}$ inch in diameter. On freshly fractured surfaces of the rock, this 'glass' is pale golden in colour, but it speedily changes colour through darker shades of green to black, and finally to ruby-red, and eventually it may suffer decomposition into a limonitic powder. Many of these spherules when decomposed show a concentric shell-like structure.

Similar colour changes were first noticed by one of us (Fermor) as long ago as 1903 in basalts being quarried near Nagpur town for road-metal.[1] In this case the 'glass' often occurred as botryoidal linings to cavities containing water, but sometimes also as shot-like spherules. The colour was then noted as changing from golden yellow to black (as viewed macroscopically) on both forms in the course of a quarter of an hour. Subsequently similar shot-like spherules were noticed in basalt quarried in the Gor river for the Bengal Nagpur Railway bridge across the Narbada south of Jabalpur; these spherules were seen to show the same colour change.

The succession of colour changes noticed in the present paper were observed particularly by one of us (Fox), who, using material collected outside the area under description, namely from a point 1 or 2 miles north of Changoba near the Betul border, attempted

[1] It was probably to this same mineral (but from different quarries) that Hislop referred as long ago as 1860 in the following words :—

'The doleritic lava, which is quarried from Sitábaldi Hill....is in some places marked with belts, that may be traced continuously for many yards, consisting of cavities "lined with obsidian in a thin glazed pellicle, occasionally filled up with tabular crystals of calc-spar."' See *Q. J. G. S.*, XVI, p. 160.

to ascertain whether the colour change was due to exposure to light or to exposure to the atmosphere. It was found that when the pale gold ' glass ' was exposed on a fresh fracture in a hand-specimen, the darkening effect began to appear at once, the black stage being reached in a couple of hours. To test the part played by light in this change, some specimens broken open in the shade were quickly wrapped in red paper and kept overnight. On removing the wrappers next morning the spherules were found to have become quite black and to show a ruby tint on translucent fractured corners. From this it was deduced that the colour change is not due to exposure to light, but to contact with the atmosphere, leading perhaps to a change of state of oxidation or hydration of the ' glass.' That this is probably not the true explanation is, however, indicated by Heddle's experiments on the chlorophæite of Scotland noticed on page 96. The ruby-coloured form is quite common on exposed surfaces and blocks of basalt belonging to this flow, but the green and gold types have never been observed except on freshly-fractured surfaces.

Compared with the open-textured and altered surface basalts, in which geodes of quartz and chalcedony are commonly found, the spherule-bearing rock is exceedingly compact and fresh ; one is consequently tempted to regard these spherules as original constituents of the lava ; but judging from the probable similarity of this ' glass ' to the chlorophæite of Rum, to be noticed immediately, and the hydrous nature of the latter, these spherules are probably of a secondary zeolitic character, analogous in origin to the palagonitic glass described by Mr. C. S. Middlemiss.[1] Judgment on this question must be reserved until we describe the microscopic and chemical characters of these lavas.

Meanwhile it may be suggested that this substance is either identical with or very similar to chlorophæite, a mineral first described and named in 1819 by Macculloch, from material obtained from Sgurr Mor (or Creag nan Stairdean) in Rum.[2] Later the mineral was analysed by Heddle,[3] whilst quite recently its occurrence in the islands of Rum and Canna has been described by

[1] *Rec. G. S. I.*, XXII, pp. 226-234, (1889).
[2] ' Description of the Western Islands of Scotland ' Vol. I, pp. 504-506.
[3] *Trans. Roy. Soc. Edinb.*, XXIX, pp. 86-88, (1880).

The colour change was noticed by Macculloch and scribed by Heddle, who writes :—

the transparent yellow-green of the finest olivine " sometimes in the ninutes it passes to a dark green-black ; and in other specimens from rown of cinnamonstone to the rich brown and brilliant jetty-lustre

piece of this mineral showing, when first broken, sive deposition, some very light, some dark green,'

exposure to sunlight this specimen, which at first was lustre like that of obsidian ; it had become in some

' By instantly after fracture wrapping up the one-half of an olive specimen tightly in repeated folds of paper, and keeping it as far as possible from exposure to air, heat, and light, I managed to retain the colour for about three weeks, only to see it lose it in about half an hour when finally exposed. The other half became perfectly black after less than an hour's exposure.'

Further :—

' Specimens securely bottled up immediately upon extraction from the rock gave on analysis very little more of ferrous oxide than those which had been freely exposed ; the change of colour therefore is not due to peroxidation of the ferrous oxide, but must be due to molecular change ; and BREWSTER [2] stated that he has optically determined that it is due to the mineral splitting up into a multitude of minute hexagonal prisms.'

The result of the former experiment disagrees with that of the experiment on the Indian specimen ; this may be due to no particular care having been taken in our case to eliminate the action of the marked diurnal range of temperatures characterising the Central Provinces during the dry season, when the experiment was made.

According to Harker [3] :—

' In a thin slice it gives a strong yellowish-brown colour, and has no sensible birefringence in the larger patches, but this seems to be explained by a very fine granular structure.'

According to the foregoing accounts the properties, both microscopic and macroscopic, of chlorophæite agree so closely with those

[1] ' Geology of the Small Isles of Inverness-shire,' *Mem. Geol. Surv. Scotland*, Expln. to Sheet 60, pp. 132, 133, and also 59, (1908).

[2] ' Reference lost.'

[3] *Loc. cit.*, p. 133.

of our Indian 'glass' spherules, that it seems highly probable that further work will prove their identity. It will be of interest, therefore, to reproduce here Heddle's analyses of the original chlorophæite of Rum, of chlorophæite from the Giant's Causeway, and of the chocolate-brown decomposition product from Rum paralleling the Indian decomposition product :—

	CHLOROPHÆITE.		Decomposition product (of Rum mineral).
	Rum.	Giant's Causeway.	
SiO_2	36·0	35·995	17·746
Al_2O_3	..	10·485	0·535
Fe_2O_3	22·8	11·89	49·672
FeO	2·462	1·026	2·147
MnO	0·5	0·077	1·196
MgO	9·5	10·517	3·988
CaO	2·52	5·15	3·07
K_2O	tr.	0·338	..
Na_2O	tr.	0·761	..
H_2O above 100°C.	7·236	9·047	11·304
H_2O at 100°C.	19·227	14·156	10·454
TOTAL	100·245	100·042	100·172
Spec. gravity	2·02 [1]	2·278	..

From this analysis it will be seen that chlorophæite is mainly a hydrous silicate of ferric iron with a considerable quantity of magne-

[1] Macculloch's determination. The totals of the first two columns are given erroneously by Heddle.

sia. This composition does not conform to any simple formula, although it approximates very roughly to $2RO. 3H_2O. Fe_2O_3.4SiO_2 + 7H_2O$. Until, however, analyses have been made both of further specimens from the Western Isles of Scotland, and of apparently similar material from other parts of the world, such as the Chhindwara area, it will not be known if chlorophæite is a definite mineral, with a definite chemical composition, or whether, as perhaps seems more likely in view both of its microscopic aspect and of its chemical composition, it is really an indefinite mixture of silicates of the nature of a hydrous glass.

In either case, in view of its hydrous composition, it seems likely that it is not a primary substance crystallised directly from the magma, but that it has filled in vesicular cavities in the lava, and is, therefore, secondary, relative to the lava. In view of the occurrence of this chlorophæite as a botryoidal lining to cavities filled with water in the basalts of Nagpur (already noted on page 94) it seems probable that chlorophæite has been deposited from water, in the same way as chalcedony and quartz.

One more point must be noticed before we leave the question of chlorophæite. Judging from the absence of any reference to the occurrence of chlorophæite in Skye in Dr. Harker's memoir on the Tertiary igneous rocks of that island, and its very local occurrence in Rum, this mineral is evidently a much less common mineral in the Western Isles of Scotland than it is in the lavas of Deccan Trap age in India. Now the material from the original locality in Rum occurs in a rock, which, although at first sight similar to basalt or dolerite in hand-specimens, has on chemical and mineralogical grounds been separated by Dr. Harker from that rock under the name of *mugearite*, the original locality being in Skye.[1] Dr. Harker also notes the occurrence of this mineral in mugearite at Eilean 'a Bhaird in the Isle of Canna, and, referring to an occurrence of chlorophæite noted by Heddle in another part of this island, he uses the words:—

> 'suggests an occurrence of mugearite not detected in the course of our survey, though it is possible that the chlorophæite occurs also in the amygdaloidal basalts.'

This association of chlorophæite with mugearite rather than dolerite may be fortuitous, but it makes it desirable for us in India to be on the alert for the occurrence of mugearite amongst the Deccan Trap flows. Chemically mugearite differs from dolerite by

[1] 'Tertiary Igneous Rocks of Skye,' pp. 264-266, (1904).

possessing a slightly higher proportion of silica, a higher percentage of alkalies, and rather low lime and magnesia. This is expressed mineralogically by the dominant constituent being a felspar—which is oligoclase with some orthoclase, instead of labradorite—whilst augite is only sparingly present ; on the other hand magnetite and apatite are unusually abundant, whilst olivine or a mica-like mineral may be present. A re-examination of our slides of flow 3 has however shown that this flow has the normal composition of a basalt or dolerite, so that in India chlorophæite, if we are correct in our identification, occurs in rock of normal basaltic or doleritic composition, instead of being characteristic of a rock of special composition.[1]

Flow 4.

Resting on flow 3 on Bandarjhiri Hill are two outliers of flow 4, separated from flow 3 by a well-defined fossiliferous band of Intertrappeans. The basalt of this flow is almost exactly like that of flow 3, but the 'glass' inclusions take the form, on fresh fractures, of green specks. Small phenocrysts of felspar are fairly common. Olivine has not been detected with any certainty in either this flow or flow 3. The surface of flow 4 on Bandarjhiri Hill has been removed by denudation, and consequently its characters cannot be given.

General succession of characters.

The aspect, both macroscopic and microscopic, of a specimen taken from any of the flows of the Linga area depends largely on the vertical position in the flow from which it has been obtained. Speaking generally the tendency is for each flow, if thick enough, to display the following succession of characters, although the tendency has not materialised in the case of flows 3 and 4, and only in a general way in the case of the remaining flows, there being always certain departures from the ideal standard succession :—

Base.—1. Fine-grained basalt with abundant phenocrysts of felspar, sometimes vesicular and zeolitic, but frequently altered more or less completely to green-earth.

2. Texture gradates to that of a true dolerite with the presence of olivine.

[1] Through the kindness of Dr. Harker I have been able to examine in the Sedgwick Museum, Cambridge, both hand-specimens and thin slices of mugearites from Skye and Rum, of chlorophæite from Rum, and of the typical basalts and dolerites of the Western Isles. The chlorophæite spots scattered through one specimen of mugearite looked exactly like our Indian mineral.—L. L. F.

3. Texture as viewed microscopically changes from granulitic or intersertal to ophitic.

Middle.—4. Passage from compact ophitic dolerite to rough-looking granular dolerite.

5. Open-textured doleritic basalt with large cavities lined with chalcedony, with quartz crystals terminating in the drusy cavities of the geodes.

6. Roughly columnar basalt, with pipe-like vesicles, some of which are filled with quartz and calcite, and are surrounded by fine-grained basalt containing much interstitial glass.

Surface.—7. Vesicular basalt with amygdales of quartz, chalcedony, banded onyx, and calcite with surface cracks and furrows.

Nomenclature.

We may close this section with a brief reference to the nomenclature of these rocks. The comparative rarity of olivine suggests andesitic affinities, and McMahon in describing the basalts of Bombay Island [1] was tempted to introduce the term augite-andesite, but refrained from so doing in view of the complete absence of hornblende ; and in consideration of this feature, and the great abundance of magnetite and augite, it is desirable to retain the terms basalt and dolerite, rather than to substitute the term augite-andesite. It would, indeed, be difficult to find more typical basalts, as distinct from olivine-basalts, than these Indian ones.

In applying the terms basalt and dolerite we have attempted to be guided by the rule that the term dolerite should be applied to those varieties in which the separate crystal individuals can be distinguished, though not necessarily identified, with the unaided eye. To all the more finely crystalline forms we have applied the term basalt. Thus, although it is not possible to distinguish with the unaided eye the separate constituents of any of the rocks classed as basalt in accordance with this criterion, yet many of them have a finely crystalline aspect. Were a separate designation required for these crystalline basalts the term anamesite might be used ; but this course seems undesirable, for even the most compact and fine-grained of basalts with the exception, of course, of the glassy form

[1] *Rec. Geol. Surv. Ind.*, XVI, p. 42, (1883).

tachylyte shows some signs of crystallinity in hand-specimens. A recent examination by one of us (Fermor) of the specimens of basic lavas of the Western Isles of Scotland arranged by Dr. Harker in the Sedgwick Museum, Cambridge, shows that this author tends to extend the term dolerite to rocks with a finer degree of grain than with us, so that some of our coarser grained basalts, particularly those that we designate doleritic basalts, would be termed dolerites by Dr. Harker.[1]

IV. THE INTERTRAPPEAN HORIZONS.

It was the existence of marked zones of Intertrappean chert between the successive lava flows, together with the green-earth bands so often characterising the bases of the flows, that alone rendered possible a definite separation of the flows one from another and their representation on the map. A short account of these horizons would, therefore, be necessary, even if not warranted by their intrinsic interest.

These Intertrappean strata are never more than a few feet, and frequently but a few inches (3 to 9), thick. They vary in character from brown chert and dark siliceous rock to soft, calcareous, lavender-coloured shale, the siliceous forms being the products of secondary silicification of the original sediments, whilst the calcareous shale is probably a comparatively unaltered sediment. It is extremely probable that much of the original sediment was fossiliferous limestone, but in many places the Intertrappean strata have been so altered (silicified) that, possibly, no portion of the original sediment is now left; abundant evidence of the original character of the rock is however, forthcoming, in the form of fossil shells, the fossil-bearing rock varying from chert full of *Physa Prinsepii* Sowerby to a calcareous rock composed almost entirely of *Limnæa* and *Paludina*. In many cases where fossils are apparently absent, a careful search leads to the discovery of minute shells of *Cypris*.

No one set of fossils is characteristic of any particular Intertrappean horizon, the fossils varying in the same band as much as the band varies in lithological character. *Physa Prinsepii* (var.

[1] Unless the fact that the dolerites described in this paper are extrusive lavas and not intrusive sills would lead Dr. Harker to apply the term basalt to the whole of the Linga series irrespective of texture.

normalis Hislop and var. *elongata* Hislop) is the commonest fossil, followed by *Paludina* (*Sankeyi* Hislop and *takliensis* Hislop), with, more rarely, *Limnæa subulata* Sowerby and *Cypris*.[1]

The fossils are sometimes entirely calcareous, but are often completely replaced by glass-clear silica, which, under the microscope, is usually cryptocrystalline.

In the northern parts of the area mapped fossils are rather less common than in the south; they are most abundant in the latitude of Linga, where they are found in each of the Intertrappean horizons 1/2, 2/3, and 3/4. The best developed horizon is that between flows 2 and 3, this band of Intertrappeans being highly fossiliferous along a belt of country stretching from Bandarjhiri Hill in the west, through Bhaurameta Hill, to Paunari in the east. In Bhaurameta Hill, where this horizon is particularly well developed, *Physa Prinsepii* is the most abundant fossil, but towards the north there is a marked change in fossil contents, *Paludina* becoming the characteristic form ; still further north there is a complete absence of fossils. Southward the horizon still contains *Physa* in the neighbourhood of Anjunia,[2] but the whole facies has become exceedingly calcareous.

Though fossils are not infrequently found in the Intertrappean horizon between flows 1 and 2, yet they are comparatively rare. The important feature of this horizon is rather the alteration of the base of flow 2: for, throughout the whole area of the map, the base of this flow, wherever it rests on flow 1, has been converted into *green-earth* to a thickness of from 2 to 12 feet. In the southern tracts, where it has been found necessary to divide the lava between flows 1 and 3 into two separate flows, namely 2 and 2A, the latter being the lower flow, the green-earth horizon characterises the base of flow 2A. At the junction between flows 2 and 2A green siliceous rock and jasper frequently occur as lenticular veins and tongues, whilst occasionally there is zeolitic matter in the soft and decomposed vesicular base of flow 2 ; but no true Intertrappean chert representing original sedimentary beds exists at this horizon.

The Intertrappean horizon between flows 3 and 4 is very similar in every way to that between flows 2 and 3, its characteristic fossil being *Physa Prinsepii* Sowerby.

[1] *Q. J. G. S.*, XVI, Plates V, IX, X, (1860). These determinations must be regarded as provisional.

[2] South of the area shown in Plate 16.

V. THE FOLDING OF THE LAVA FLOWS.

General horizontality of the traps.

Perhaps the most striking feature of the Deccan Trap formation is the general horizontality of the lava flows of which it is composed. This has been commented on by numerous observers in the past, and can easily be verified nowadays by anyone who looks out of the train during what must always remain to the geologist one of the most remarkable railway journeys in the world, namely that from Bombay to Nagpur, a distance of 520 miles, entirely over Deccan Trap lavas, covered in places, of course, by alluvium and soil.

But although the phrase *horizontality of the traps* so frequently met with in Indian geological literature expresses well the general aspect of this remarkable formation, yet in certain regions there are marked departures from horizontality, as was recognised and described by W. T. Blanford and others more than 40 years ago. The knowledge on this subject was summarised by W. T. Blanford in the following words [1]:—

'A remarkable horizontality persists throughout the greater part of the trap area, the most important exception being in the Rajpipla hills, and the ranges immediately north of the Narbadá, in parts of the Satpúra hills north of Khandesh, and along the coast from Bombay to Damán. In these exceptional areas the dips are clearly due to disturbance subsequent in date to the consolidation of the rocks, for sedimentary beds, which must originally have been horizontal, have shared in the movement. It is thus clear that throughout the area the traps must have originally been nearly level.'

In addition to the marked dips referred to by Blanford, which, where they occur, often affect the disposition of the lavas over a considerable area, there may be detected in places very gentle dips, also existing over considerable distances. As bearing on this question we may, with advantage, quote the following lines from the second edition of the Manual of the Geology of India, 1893, page 261:—

'The only departure from absolute horizontality to be seen in the lava flows of the Deccan is frequently no more than may be due to the lenticular form of the beds, but usually there is a very low dip discernible, seldom exceeding 1° and fairly constant over large areas. This circumstance tends to show that even this small amount of inclination may be due to disturbance, because if the dips represented the original angle at which the lava flows were consolidated, they would be found to radiate from the original volcanic vents. Nothing of the kind has, however, been traced.'

[1] *Rec. Geol. Surv. Ind.*, V, p. 90, (1872).

Finally, in areas in which the lavas appear to be perfectly horizontal or to have only the slight dips referred to in the last paragraph, careful examination may lead to the discovery of sharp dips of but local extension. It is a case of this sort that we have discovered in the Linga tract. These local dips are not so unimportant as they might seem at first sight, for they are arranged along a series of anticlinal and synclinal axes, thus showing that a series of lavas of general horizontal appearance may carry the impress, in the form of a series of gentle folds, of the application of tectonic pressures on a regional scale. In the same way a series of horizontal lavas may really be traversed by faults, which owing to the similar nature of the rocks on either side of the fault escape detection, except as the result of very careful work. Some faults of this character are considered in section VI of this paper.

Previous records of disturbances in the Deccan Trap.

Before entering upon our account of the Linga folding it is desirable to refer to a selection of the previous records of departure from horizontality in the Deccan Trap lavas.

In his paper 'On the Trap and Intertrappean Beds of Western and Central India,' published in 1867,[1] Dr. W. T. Blanford gives one of the best accounts yet published of the general disposition and age of the Deccan Trap lavas and associated Intertrappean beds. On page 151 (*l. c.*) there is a figure of a striking section showing the horizontal character of the traps of the Western Ghats as far west as Panwel, followed by a steady dip at from 5° to 10° to the west over a distance of 10 to 12 miles, this dip persisting from Panwel to the sea at the islands of Bombay and Salsette. In another more detailed Memoir entitled 'On the Geology of the Taptee and Lower Nerbudda valleys and some adjoining districts,'[2] Blanford describes at some length the geology of a large tract of country, much of which is occupied by the Deccan Trap formation. Although as a general rule the traps rest in perfect horizontality over a considerable portion of this country, yet in many parts dips, ranging from 2° to 25° were measured. Thus (p. 220) :—

'Along the line of the Taptee south-west of Baitool there is marked southerly dip, though at a low angle, and although the beds are horizontal throughout a large portion of the Gawilgurh hills, there is a dip of about 5° to 10° to the north along

[1] *Memoirs, Geol. Surv. Ind.*, VI, pp. 137-162.

[2] *Mem. Geol. Surv. Ind.*, VI, (1869). Consult, for accounts of dips and faults in the traps, pp. 219-221, 224, 266 (figure), 271, 279 (fault), 280 (fig.), 281, 282 (fig.), 283, 288, 289, 307, 310 (fault); 313 (fig.), 325-6 (fig. and fault), 345, 353, 371 (fault), and other pages.

their southern scarp accompanied, apparently, by a great fault at their base parallel to the range. Passing to the westward, low dips in various directions are seen amongst the traps of the Satpoora hills. These increase in amounts here and there. Some very sharp dips of 10° and even more to the southward are seen in the Nerbudda and just north of the river west of the Hurin Pal; ....which continues for many miles to the westward....... The amount of disturbance which the traps have undergone appears to culminate in the Rajpeepla hills. Not only do the beds in this region dip at angles comparatively high (5° to 20°) when their horizontality over immense tracts in the Deccan and Malwa is considered, but dykes are extremely prevalent, and of great size ....'

When all the dips mentioned by Blanford in his memoir are plotted on a map it is found that by far the larger number of them are directed either to the south or to the north, arranging themselves along lines running east and west, so as to indicate a regional compression of the whole of this immense tract of country in posttrappean times by pressures directed from the north and south. Most of the faults mentioned by Blanford have also an east-west alignment.

A. B. Wynne in 1872 [1] mentions a general southerly dip of 2° to 5° in the flows of Kachh, with an anticlinal fold in the Chitrana hills in this area, as well as faulting at some localities. The dip of the Kachh lavas had already been noticed by Blanford.[2] In a later memoir on the geology of the Nagpur district, Blanford mentions a case at Kelod of faulting of Kamthi rocks against Intertrappeans.[3] Proceeding further south we find that R. Bruee Foote, in his account of the geology of the Southern Mahratta country [4] mentions a very slight north-easterly dip in the trap flows of the Western Ghats of that region, the dip being too slight for measurement with a clinometer; it was calculated, from the difference in elevation of some of the principal trigonometrical stations capped by outliers of one and the same bed, as ranging from 9 to 23 feet per mile, with an average of 16 feet per mile.

In more recent years we have our colleague Mr. E. Vredenburg's paper on Pleistocene movements in the Indian Peninsula,[5] in which, from a consideration of the variations in gradient of the Narbada, Purna, and Godaveri rivers, it is deduced that the Peninsula has been warped about a very gentle anticlinal axis of N. N. E. to S. S. W. strike, running across this Trap area of Western India.

[1] *Mem. Geol. Surv. Ind.*, IX, pp. 59, 187, 262, and map Plate VI.
[2] *Mem. Geol. Surv. Ind.*, VI, p. 30, (1867).
[3] *Mem. Geol. Surv. Ind.*, IX, pp. 21-22, (1872).
[4] *Mem. Geol. Surv. Ind.*, XII, p. 173, (1876).
[5] *Rec. Geol. Surv. Ind.*, XXXIII, pp. 33-45, (1906).

Lastly, the Rev. S. Hislop, in his paper 'On the Tertiary Deposits, associated with Trap-rock, in the East Indies',[1] explicitly mentions 'an anticlinal axis on a small scale' near Telankhedi in the Nagpur district, a dip of 30° to the west being mentioned. He does not, however, explain the anticline as due to tectonic causes, but adduces his observations to prove the intrusive laccolitic or sill-like character of a sheet of basalt with reference to an overlying Intertrappean band and lava flow. Blanford has long since refuted the suggestion of the intrusive origin of this sheet of basalt, which is one of the ordinary succession of flows ; and there seems little doubt that Hislop's anticline must be of tectonic origin, supposing it really exist, for Blanford omits all reference to it in his memoir on the geology of the Nagpur district already cited. In this connection it is interesting to note that Hislop's anticline runs north and south, *i.e.*, roughly at right angles to the direction of the folding detected by us in the Linga area, which lies almost due north of Nagpur, but roughly parallel to Mr. Vredenburg's warp-axes.

Folding of the Linga area.

The result of our work in the Linga area has been to show that in an apparently typical area of general horizontality there are numerous dips, which, when interpreted, reveal the presence of a system of folding due apparently to tectonic causes. From this we deduce that probably many other areas of apparently horizontal lavas when closely studied will yield information of value in tracing the tectonic history of the Indian Peninsula. Consequently it is of considerable importance to give a moderately detailed account of the system of folding detected in the Linga area, and to draw from it such conclusions as seem to follow.

In studying this area we soon found that the only sure way of mapping the separate flows was to follow carefully the Intertrappean bands ; this led to the unexpected discovery of numerous examples of marked dips ranging up to 10° and 15° and, very rarely, up to 45° and 90°, in Intertrappean rocks of undoubted sedimentary origin, as testified by the frequent presence of the fossils already noticed in the previous section. Along a north-south section of the country these dips were found to be directed alternately to north and to south, but to maintain their direction (to the north or the south) when traced in an E-W direction. Whilst, however, the more

[1] *Q. J. G. S.*, XVI, p. 156, (1860).

marked dips were directly observed, others, of a much gentler nature, were detected from barometric readings carried out originally with the idea of tracing the adjustment of the flows to the pre-Trappean topography. The various dips are shown on the accompanying map (Plate 16), those directly observed being indicated by a simple dip arrow, whilst those deduced barometrically are distinguished by the letter B.

Although the assembled data suggest a regular series of gentle folds, yet in the field there was at first ample room for doubt as to the interpretation of some of these dips, particularly of those deduced barometrically, which were at first attributed to the adjustment of the flows to the contours of the underlying pre-Trappean surface. But although, possibly, this factor plays some part (see page 88), yet we now agree that by far the greater number of dips observed is really due to a system of folding.

Anticlines and synclines.

The general existence of synclines and anticlines can be easily deduced from the distribution of the lava flows as shown on the map compared with the courses of the rivers, the alternation first of flows 2 and 1, and then of flows 2A and 1, along the course of the Kulbehra, being the most noticeable feature. The exact placing of the axes of the folds is, however, more difficult; but we have, we believe, attained a certain measure of success.

The axis of the first syncline is at about the latitude of Imlikhera, the dolerites of flow 2 here occupying the bed of the Kulbehra; the basal green-earth of this flow can readily be traced downward into this synclinal trough both from the north and from the south. The first anticline, that of Shikarpur, is exceedingly gentle, contrasting thus with the comparatively sharp syncline of Imlikhera to the north and of Dewardha to the south.

The Dewardha, or second, syncline agrees roughly in position and direction with the easterly reach of the Kulbehra river just north of Dewardha. Exposures of the columnar basalt of flow 3 in the railway quarries close to the river, just before it takes this easterly bend, show variations in the hade of the columns concordant with the presence of a syncline at this point, but it cannot be regarded as certain that this arrangement of the columns is not an original cooling effect. The Intertrappean beds on the southern side of this syncline dip steeply to the north, as is well seen in exposures on either side of the Nagpur road close to milestone 6 from Chhindwara.

These high dips are doubtless related to the strike fault described on page 118. Linga village stands approximately on the axis of the second anticline, the continuance of which to the W. N. W. is indicated by several inliers of flow 1 near Bargona.

Jaitpur is situated on the northern limb of the third syncline, a well-marked dip of 12° being seen in the Kulbehra immediately south of the village. Goreghat is situated practically on the axis of this syncline, which is followed by an upward rise towards Sarora village. The next or third anticlinal axis passes along the Sarora ridge, and from here the lava sheets dip southward.

A line trending W. N. W. to E. S. E. through the village of Chikhli marks the position of the axis of the fourth, or Chikhli, syncline. A very fine exposure showing a marked northerly dip (15°-40°) is seen in the north bank of the Baradoi Nala by the palm-tree (shown on the map) south-west of Chikhli. Northerly dips are maintained up the Baradoi Nala to the west. The
between flows 2 and 3 on Lahgarua Hill is
the same horizon in the hill to the north,
e of which it seems that the axis of the
nues to the east. Lahgarua village itself
on the next anticlinal axis, and from a general
examination of the country still further south it seems that other synclines and anticlines continue to occur.

The average distance between these folds is about 2 miles from anticline to anticline; but a study of the dips recorded on the map suggests that there may be some subsidiary folds intercalated between the foregoing principal folds. Thus there are indications of an additional syncline and anticline between the Linga anticline and the Goreghat syncline; of an additional syncline and anticline between the Sarora anticline and the Chikhli syncline; and of an additional anticline and syncline between the Chikhli syncline and the Lahgarua anticline. These subsidiary folds all possess, of course, the customary E. by S. strike; but the series of inliers of flow 1 between Bargona and Palamau may indicate either the presence of two small synclinal puckers of N. E. and N. N. E. strike respectively, or be due to irregularities in the underlying pre-trappean surface.

Monoclinal tendencies.

Discussing now the principal folds, we find that although the folds persist for considerable distances in the directions of their axes, yet these axes show

distinct signs of curvature, whilst the folds themselves are exceedingly gentle. Thus, in the case of the Linga anticline, the height of the base of flow 2 under Linga village is not much more than 200 feet above the same horizon in the trough south of Jaitpur. The synclinal portions of the folds are apparently more pronounced and more compressed than the anticlinal portions, whilst the northerly dips generally appear to be steeper than those to the south. The apparent paradox of such steep dips as 12° to 40° recorded above, and the exceedingly shallow character of the folds indicates that the central portions of the limbs of these folds must often show a sudden increase of dip followed by as sudden a decrease. So that in place of a perfectly graded series of anticlines and synclines there tends to be a series of short steep monoclinal segments of alternately northerly and southerly dip connecting long, nearly horizontal, segments which are alternately raised and depressed. The monoclinal tendency has apparently been accentuated by the small strike faults noticed in the next section of this paper.

General slight S. E. dip of the Linga flows.

In addition to the marked dips observed at various points, due to the gentle folding of the traps just described, the lava sheets taken as a whole have an extremely gentle dip to the S. E. This is deduced from barometric readings for the base of any given flow taken along various lines of section across the area mapped. Thus the following set of figures shows a decrease in the elevation of the base of flow 3 amounting to 220 feet in the course of about 8 miles from north to south :—

	Feet.
A point S. E. of Khunajhir Khurd	2,290
Bhaurameta Hill	2,240
Lahgarua Hill	2,190
Umra Nala	2,070

Whilst the following set of readings taken in an east by slightly south direction from the same point near Khunajhir Khurd shows a decrease in average elevation of the same horizon of 160 feet in about 6 miles :—

	Feet.
S. E. of Khunajhir Khurd	2,290
Outlier W. of do.	2,250
N. scarp S. S. E. of Tiura Kamtha	2,280
S. scarp due S. of do.	2,230

	Feet.
Outlier N. of Bargona	2,225
W. point S. of Khunajhir Kalan	2,185
N. scarp N. N. W. of Linga (on Nagpur road)	2,135
S. scarp do. do. do.	2,110
Bengal Nagpur Railway cutting	2,065
Scarp N. of Paunari	2,085
Outlier N. E. of Paunari	2,130

A pre-trappean valley.

The rise shown by the last two readings is interpreted as an indication of the existence of a north-south trending sag in the lava flows, due probably to a pre-trappean valley (page 88). The dip of 220 feet in 8 miles from north to south, and of 160 feet in 6 miles from W. by N. to E. by S. corresponds to a slope of 35 feet per mile to the S. E.

Inclination of onyx geodes.

At this point it is necessary to refer to a series of observations of the inclination shown by the layers of chalcedony in geodic onyx. Many of the geodes occurring in the upper portions of the flows are of composite character, consisting below of onyx built up of parallel bands of chalcedony doubtless deposited from solution in the horizontal position, with the upper portion of the geode filled with crystalline quartz, deposited after the onyx. On weathered surfaces of the flows the quartz has often been removed so as to leave a plane and apparently horizontal surface of onyx, on which it is possible to rest an Abney's level and measure the angle of dip. The following series of observations was taken on onyx geodes in the surface of flow 2A in the Baradoi Nala close to the palm-tree exposure S. W. of Chikhli, at which point the Intertrappeans between flows 2A and 1 are dipping north at angles of from 10° to 15°:

No. of observation.	Amount of dip to N. N. E.	Amount of dip to E. S. E.
1	0°	½°
2	0°	1½°
3	1½°	1°
4	½°	1½°
5	0°	2°
6	0°	1°
7	0°	¾°

From these figures it will be seen that although the dip of the Intertrappean layer in this locality is to the north, yet the geodes indicate a slight yet distinct dip to the E. S. E.

Summary of structural features.

The structural features of the basaltic sheets of this area thus elucidated could be illustrated by means of a corrugated plate held with its N. W. corner slightly elevated and its S. E. corner slightly depressed, and the corrugations (in monoclinal flexures) oriented W. N. W. to E. S. E. (more exactly, about W. 12° N. to E. 12° S.) and placed rather closer together in the north; for completeness the plate might be gently indented along a north-south line towards the eastern margin.

The points we have elucidated in connection with the departures from horizontality in the traps of the Linga area may now be summarised. They are—

1. the main trend of the anticlinal and synclinal axes is roughly W. N. W. and E. S. E.:
2. the entire block of lava flows shows the very slight dip of 35 feet to the mile in a S. E. direction:
3. the geodes in the Baradoi Nala show an average dip of slightly more than 1° to the E. S. E., *i.e.*, at right angles to the direction of the fold-dips seen in the Intertrappean layers:
4. evidence for three faults has been obtained (see next section), the direction varying from E. S. E. to E. by N.

The Deccan Trap succession.

Before discussing the meaning of each of the foregoing points it is desirable to note the position of the Chhindwara lavas in the whole Deccan Trap succession. The classification of this formation given in the 2nd Edition of the 'Manual of the Geology of India' by Medlicott and Blanford, revised by R. D. Oldham, p. 262, (1893), is as follows:—

	Approximate thickness in feet.
1. Upper traps, with numerous beds of volcanic ash and the intertrappean sedimentary deposits of Bombay	1,500

flowing water in rivers. For the purposes of comparison the following figures for water are given[1]:—

	Fall per mile.
Non-torrential rivers—	
Narbada, for 300 miles above Handia	1½ feet.
Missouri	28 ins.
Thames	21 ,,
Shannon	11 ,,
Nile below Cairo	3·25—5·5 ,,
Volga	3 ,,
Torrential rivers—	
Durance	11·3—25·4 feet.
Arve	8·6 ,,
Colorado, cañon section	7·7 ,,

In comparison with the figures for non-torrential rivers the value of 35 feet per mile for molten basalt seems rather high; but it must be remembered that the rivers have by their own powers of erosion reduced the gradient to that recorded, whilst the lava has adjusted itself to such slopes as it found in its course. If, however, we compare the slope of the lava with those of torrential rivers, then the figures are as close as one wouldex pect for substances of such different viscosities. It looks therefore, as if we may regard the dip of 35 feet to the mile as the true flow dip of the basalt of this area. But in view of the great distances to which the lava sheets have flowed before solidifying, it is probable that basaltic lava could flow over a still more gentle slope although to a lesser distance, other factors being the same. Consequently we must not be surprised if future measurements of the angle of flow of the Indian basaltic lavas sometimes yield smaller values than that here recorded, as well as, of course, higher ones.[2]

In the foregoing paragraph we have deduced that it is more probable that the S. E. dip of the traps of 35 feet to the mile is due to flow than to tectonic causes. This is not certain, however, and therefore it will be well to consider the other possibility. Should future measurements show that the geode dips are not merely local but regional, then it will be necessary to admit the existence of a

[1] Gradient of Narbada according to E. Vredenburg, *Rec. G. S. I.*, XXXIII, p. 37, (1906); remainder from Geikie's 'Text-book of Geology,' 4th Edit., p. 486, (1903).

[2] The basaltic lava slopes of Kilauea, in the Sandwich Islands, have an angle sometimes as great as 10°, but 'occasionally a lava stream may descend a steep slope or even take a precipitate plunge without interruption of continuity, so that the mass resembles a frozen cascade.' See T. G. Bonney, 'Volcanoes,' p. 58, (1912).

S. E. tilt of the traps of later date than the folding, in which case it will no longer be possible to interpret the barometrically-detected dip of the traps as due to original flow. But even if future work show that the geode dips are purely local, it is still not quite certain that the S. E. dip of the traps is due to flow. It might be due to a regional tilt either contemporaneous with or subsequent to the folding of the flows.

We have already referred on page 105 to Mr. Vredenburg's deduction of the existence of an anticlinal axis of N. N. E. strike and Pleistocene age lying to the west of the Narbada and Purna alluvial patches. On page 42 (*l.c.*) he writes :—

> 'It will be asked, perhaps, how it is that no indication of this warping should have been noticed in the nearly horizontal Deccan Trap formation? But it must be remembered that, while its effects may seem very evident on the diagrammatic profiles of the river-courses, with their enormously exaggerated vertical scale, the amplitude of the oscillations relatively to the large areas affected is so small that it would, no doubt, require a minutely detailed survey to detect any consequent tilting of the volcanic beds.'

At first sight it might appear that in this S. E. dip of 35 feet to the mile we have found just the expected effect of Mr. Vredenburg's N. N. E. Pleistocene warp-axis. A slight calculation shows, however, that we have no data for making this correlation. The distance of Gadawara from the point where Mr. Vredenburg's axis crosses the Narbada river is about 130 miles in a straight line, and from the lower end of the Narbada alluvium at Handia it is about 110 miles. If the bottom of the basin in which the Narbada alluvium is contained sloped at an angle of 35 feet to the mile from Handia to a point opposite Gadawara, then at the latter point it would be 3,850 feet deep, or, allowing for the gradient of the river, about 4,000 feet below the surface. The only evidence that we have as to the depth of the Narbada alluvium is derived from the Gadawara boring, which was carried to a depth of 491 feet without reaching the base of the alluvial formations. It is not unlikely that the alluvium extends to a considerably greater depth than this in the centre of the basin, but we are not, on the evidence available, justified in assuming such a depth as 4,000 feet. We cannot, therefore, regard the dip of 35 feet to the mile in the Linga traps as due to the Pleistocene warping, although we cannot deny the possibility.

Hence at present the balance of probabilities points to the S. E. dip of the Linga traps being a flow dip.

D 2

VI. FAULTS.

In April 1913, we revisited Linga in order to make a brief joint examination at certain points and test the map as finally revised after the finish of the previous season's work, and particularly for the purpose of unravelling certain difficulties in the neighbourhood of Paunari and Dewardha. After a little search we found that a fault running in an average E. S. E. direction from a point on the Nagpur road a little north of milestone 6 to a point N. E. of Paunari, a total distance of about 1½ miles, would explain all our difficulties. Once we had proved definitely the existence of the Paunari fault, the desirability of inserting on the map two other faults—near Salimeta and Jaitpur respectively—became evident. In spite of the numerous cases in various parts of India of disturbances in the Deccan Trap formation, sometimes accompanied by faulting, as referred to in the previous chapter, yet faults in this formation are, as at present known, sufficiently rare to make it desirable to state in detail the evidence for the existence of faults in the Linga area.

The Paunari fault.

The Paunari fault is most clearly traceable at its eastern end. On travelling downstream on the left bank of the Kulbehra from the sharp bend about ½ mile north of Paunari, one finds the dolerites of flow 2 well exposed, first as a series of terraces with an average horizontal dip (but with local dips, in one place as high as 25° to E. 30° N.), and then as a cliff, jointed into angular blocks, which are bounded by plane, concave, and convex surfaces and tend towards rudely columnar shapes; this latter is the typical basal dolerite of flow 2, the flaggy form being due to one variety of this jointing. The total thickness of dolerite seen above the surface of the river is about 35 feet.

After alluvial material for a short distance in the bed of the river, numerous outcrops of dolerite stretch down stream past Paunari. At first, when the work was based on lithological distinctions, these two dolerites were thought to be parts of the same flow; but subsequent mapping showed that the rocks seen in the river-bed from Paunari past Goreghat, as far as the latitude of Bisapur Kalan, must be regarded as belonging to the basal flow 1, whilst the jointed dolerites already mentioned belong to flow 2. A small quantity of Intertrappean chert and green-earth in the left bank of the Kulbehra

between these two dolerites was then thought to indicate a dip of flow 1 under flow 2. The rocks of Paunari Hill, on which stands the village, consist largely of nodular basalt, and from their position must also be referred to flow 2; their dissimilar lithological character from the jointed dolerites seen in the river cliff is partly discounted by the presence of scattered fragments of flaggy and jointed dolerites on the top of the hill. Flow 2 of this hill is separated from flow 1 by green-earth underlain by Intertrappean chert, one or other of which can be traced nearly continuously round the hill. But at the N. E. end of the hill this girdle of Intertrappean material is incomplete, and, instead, two belts of green-earth-strewn ground run northwards across the more southerly of two cart-tracks. The eastern belt of green-earth is specially instructive, as it terminates very sharply to the N. N. E. and is then replaced by red soil. This is the most easterly evidence of the existence of the fault. The western belt of green-earth cannot be traced so far, but the Intertrappean chert, sometimes carrying shells, just crosses the more northern cart-track, and then swings round to the W. N. W., soon terminating. This chert is brecciated in places, and the brecciation and the rapid termination of the horizon to the west are interpreted as marking the position of the fault. The ground to the north of the presumed position of the fault is also slightly higher and of boulder-strewn, uneven character, contrasting clearly with the smoother ground to the south of the fault. Further west the ground south of the fault shows abundant exposures of the jointed vesicular basaltic surface of flow 1, which is traceable to the S. W. into the underlying dolerites west of Paunari, and to the W. N. W. into a section of columnar doleritic basalt, in a ravine in the river bank, less than 100 yards south of the end of the cliff of jointed dolerites of flow 2. The columnar rock of flow 1 is on the same horizontal level as the cliff of flow 2, whilst the columns are vertical, giving no evidence of a dip in flow 1 that would carry it below flow 2. The river-bank between these two points is alluvial, but there seems to be no escape from the conclusion that the fault enters the river at this point.

Across the river the bank is entirely alluvial for some distance and there is no evidence either for or against a fault. Tramping across fields one reaches the railway cutting at Dewardha. This cutting shows jointed dolerites of flow 2 for some distance southwards from the river bank; but at the point where the fault has

been carried across the line on the map, there is a zone some 3 feet wide of excessively jointed or fractured dolerite, and this is doubtfully accepted as marking the position of the continuation of the Paunari fault. Some 70 to 80 yards further south the cutting shows only soil, which gives another possible position, if the fracture-zone noticed above does not mark the position of the fault. Proceeding W. N. W. one crosses more fields as far as the nala shown on the map. The ground is here exceedingly difficult to unravel, but we think that the best interpretation is that a tongue of flow 3 occupying a slight depression extends southwards from the main ridge of that flow and has its southern end faulted up as indicated. The distribution of such green-earth and chert exposures and fragments as we could find agreed on the whole with this interpretation.

The next point where there is any evidence of the existence of a fault is in a well in flow 2, just below the scarp of flow 3 at a point some 150 yards east of the Nagpur road. This well shows decomposed trap with a vertical band of chert starting from the bank on the west side of the well with a thickness of 1½ to 2 feet, becoming thinner in depth, and re-appearing in the east wall of the well as three interrupted vertical seams; there is also an isolated fragment in the trap. Although the exact interpretation is not clear, it is evident that the rocks have been violently disturbed and fractured at this point. Exposures of Intertrappean fossiliferous cherts are seen on each side of the road; that on the west side shows about 3 feet of this chert resting on decomposed earthy trap and having a dip of 40° to the north. Some 5 feet south of the Intertrappean band, the decomposed trap shows a vertical band of chert a few inches thick, which can be interpretated as having been separated from the main mass of Intertrappean chert by an earth movement. This is as far west as any evidence of disturbance attributable to faulting can be detected. We have connected all the points by one slightly sinuous fault, but it is, of course, possible that there is a zone of parallel or branching faults in this neighbourhood.

Assuming the representation on the map to be correct, we see, starting from the east end, that the fault first runs W. 35° N., and then W. 15-20° N. to the river bank. It then continues with a wavy course of average W. N. W. direction as far as the well, whence it makes a sharp turn to the W. 30° S. to the road. Perhaps at this point a subsidiary fault really commences.

The down-throw of the Paunari fault is to the north, and judging from the juxtaposition of the exposures of flows 1 and 2 in the Kulbehra, the amount cannot be less than 35 feet, whilst it is probably at least 50 feet. It may, of course, be greater—say up to 80 to 100 feet—but this is a maximum, as otherwise flow 3 would have been brought into contact with flow 1. Judging from the map it is evident that the throw of the fault decreases to the west.

A subsidiary fault at Paunari.

In addition to the main Paunari fault, it is necessary to insert a much smaller one in the river bank at the spot shown, in order to explain the presence of the small exposure of green-earth and of Intertrappean chert already referred to. The chert has a dip of about 20° to the N. N. E. The fault must have a slight down-throw to the south, decreasing to *nil* in either direction on the strike.

The Salimeta fault.

A somewhat brecciated chert band with a westerly strike is traceable for several yards in a nala ¼ mile north of Salimeta village. It is 2 to 3 feet thick, and vertical like a vein. This is interpreted as marking the position of a line of fracture, but there is no evidence as to the direction or extent of the throw, if any. Three-eighths of a mile further west and about ¼ mile east of Jamun village there is a small ridge capped with fragments (1) of dark grey Intertrappean chert with shell remains, and (2) of green jasper. The exact interpretation is doubtful, but the fragments may mark the continuation of the Salimeta disturbance. If so, then the presence of the fossiliferous chert can be best explained by supposing it to have been brought up by the fault from the Intertrappean horizon between flows 2 and 1, which is not far below the surface just here, whilst the formation of the green jasper may be connected with the fault itself. The throw of the fault would then be not less than the distance from the top of the ridge to the Intertrappean horizon between flows 2 and 1; there is no evidence as to the direction of throw.

The Jaitpur fault.

At Jaitpur the relationships of flows 1 and 2 to each other are such that they might conceivably be explained either by folding alone or by a combination of folding with a fault. Fig. 2 of Plate 15, which is roughly to scale, shows a possible interpretation. On the north bank of the river the green-earth horizon (consisting of 6 to 7 feet of green-earth

with a basal layer of cream-coloured clay one foot thick) occurs at an altitude of 1,990 feet, and is succeeded downwards by very vesicular lava typical of the top of flow 1, and this by vesicular dolerite, underlying which is non-vesicular dolerite. Still nearer the bed of the river the bank is entirely alluvial. In the river-bed itself (1,945 feet) there is a succession of outcrops of the typical surface of flow 1, but in the south bank the Intertrappean horizon separating flows 1 and 2 is found practically at water level, dipping at 12° (10° to 15°) to the south under flow 2 and resting on the decomposed vesicular surface of flow 1. This Intertrappean horizon consists of fossiliferous chert overlying green-earth, the total thickness being about 3 feet. As shown in the figure, a southerly dip of 12° produced upwards to the north would carry the Intertrappean horizon well above the green-earth horizon in the north bank (along CD); by lowering this horizon it could be carried into the green-earth horizon at A, but at whatever angle it were bent so as to clear the alluvial bank at B it could not be brought to within less than 15 to 20 feet from the surface of flow 1 on the northern side of the river-bed. But as this, judging from its physical characters, can hardly represent a portion of the flow so far below the surface, it follows that the 12° dip seen on the south bank of the river lessens so sharply to the north that there must be, approximately in the position shown, either a fault with a small throw to the south, as has been indicated on the section and the map, or, perhaps less probably, a monoclinal fold at the same point.

VII. THE CRATERLETS.

An account of the discovery of a series of curious circular hollows in the basaltic bed of the Kulbehra river opposite the village of Shikarpur has already been given in a previous volume of these *Records* (Vol. XLII, p. 90, (1912)), where they are designated '*craterlets*.'

The distribution of the flow to which they belong—namely flow 1—has been described in section II, and needs no further consideration, because a careful examination of the numerous inliers of this flow has not revealed the existence of a single example of these craterlets outside the Shikarpur reach of the Kulbehra river, in which they were originally discovered, and where they occur to the number of about 20, scattered over a distance of some 1,600 feet.

As structures resembling these craterlets are not known to occur anywhere else throughout the immense area of country covered by the Deccan Trap lavas, the Shikarpur craterlets are bound to be of considerable interest, and an object of pilgrimage to most geologists visiting Chhindwara; they may also excite some popular interest. We have, therefore, thought it desirable to append a plan (Plate 15, fig. 1) showing their arrangement, and, for purposes of description, have assigned to each a number.

The easiest way of reaching the craterlets is to travel some 5 miles south from Chhindwara along the Nagpur road, and then strike due east across fields for about ¾ mile. When projecting a visit it should be remembered that the craterlets are situated in the bed of a river and are, therefore, in all probability, entirely under water during the monsoon. Even in November, when we first visited Shikarpur, some of the craterlets were still partly under water; but at any time between the beginning of November (or perhaps the middle of October) and the break of the rains in June they are probably sufficiently exposed, except after prolonged and exceptionally heavy rain storms, to repay a visit.

On examining the rocky bed in which these craterlets are situated it becomes evident at once that this is approximately the original surface of a lava flow, which happens to be no. 1 in the series; the basal flaggy dolerites of flow 2 are seen in both banks of the river underlain by a series of banded clays.

The surface of the flow.

For the moment ignoring the craterlets, we must first notice the character of the surface of the flow. The lava is here full of vesicles averaging ⅛ to ¼ inch in diameter, and also contains many small amygdales, as well as large geodes of quartz, chalcedony, etc., such constituents being of course typical of the surface of a flow. Further, it is traversed by numerous, approximately vertical, master cracks, from either side of which spring smaller cracks, causing a tendency towards a rudely columnar structure, the whole being extremely suggestive of cooling cracks at the free surface of a lava flow. The strength of this impression is increased by the character of the surface of the lava immediately east of craterlet no. 4, where there seem to be parallel streams of vesicular lava aligned in a N. by W. direction, with parallel waved master cracks, and jointing at right angles to these cracks. The lava is also striated in the same direction, and one feels convinced that N. 6° W. to S. 6° E. is the direc-

tion of flow.[1] The character of the surface of the flow is well shown in figure 1 of Plate 2.

Distribution of the craterlets.

The craterlets themselves are distributed very irregularly over the surface of the flow, and, as will be seen from the plan (Plate 15), are aligned in a general N. by E. direction. This alignment may be merely apparent, due to the direction of this reach of the river, other craterlets being hidden under the banks on either side. But the absence of any craterlets in the Kharak stream, which joins the Kulbehra about ½ mile below Shikarpur, may mean that the craterlets are really aligned in a N. by E. direction and that this disposition indicates roughly the direction of flow of the lava, the evidence of the craterlets then agreeing roughly with that of the cooling cracks and the striation of the flow as noticed in the preceding paragraph.

Characters of the craterlets.

The craterlets are of very different sizes and shapes. Speaking generally they are circular hollows varying in internal diameter from 3 to 20 feet, the largest being no. 5 which measures $23' \times 18'$. In some cases the circle looks as perfect as if drawn with a pair of compasses, *e.g.*, no. 10 (16 feet diameter) for which see Plate 10, fig. 1. In other cases the shape may be oval or even more irregular owing to a more complex character than usual, as in no. 11 (an ovoid), no. 8A (a horseshoe), and no. 3A (showing two cells or hollows). The wall of a craterlet is usually from 1 to 3 feet higher than the centre, but no. 3 is 5 feet deep; the heights above the lava outside the hollows are of similar magnitude.

Whereas the lava both outside and inside the craterlets is usually very vesicular, that composing the walls themselves is an almost non-vesicular variety, much more resistant to weathering. It sometimes shows a roughly columnar structure of radial disposition, well illustrated in no. 3 (see Plate 11). In this, the best example, the columns are 1 to 2 feet long; the inner ends are non-vesicular, and the remainder increasingly vesicular with distance from the interior of the hollow. The walls or rims of the craterlets are generally from 1 to 3 feet thick, but may be as much as 4 feet, as in no. 9 (a fort-like mass), or as little as 8 inches, as in no. 8.

It is difficult to determine the exact nature and significance of these craterlets. In the first place their present shape is no doubt partly the result of differential denudation acting unevenly on the

[1] The striation may be the effect of erosion.

non-vesicular rock of the rims and the vesicular rock outside and inside the craterlets; but the total amount of denudation cannot be great, since, leaving out of consideration for the moment the characters of the flow itself, it is evident from the position of flow 2 that it has only just been removed. In a few cases it seems possible that the craterlets have acted as vents for lava. Thus in the case of no. 3 some vesicular trap piled up outside appears to be derived from the craterlet, although this may be the effect of denudation. On the other hand, no. 11 has its walls breached at two points, with streams of lava of comparatively non-vesicular character, like the rim, flowing into the craterlet from outside.

Microscopic examination does not reveal much difference between the rocks of the rim and the vesicular lavas outside and inside the craterlets. All the thin sections show augite, plagioclase, and magnetite, with interstitial black original glass, and various secondary products (glass and serpentine), of which the serpentine suggests olivine outlines. The rocks of the rim have about the same grain as the others, but tend, perhaps, to be slightly finer grained, they also tend to contain larger patches of black glass full of microlites than the vesicular rocks; but, on the other hand, they are comparatively free from vesicles, and therefore contain less of the secondary orange glass.

Judging from the microscope it is evident that the chief difference between the rocks of the rims and the vesicular lava lies in the vesicular character. The rate of cooling of each was approximately the same, the rim rock having cooled slightly more rapidly, if anything. These facts seem explicable in only one way. The rims must have remained liquid or plastic after the similar lava outside had solidified, this longer persistence of liquidity helping the escape of the steam or other gases that produce the vesicles. But when the rims did solidify it seems as if they cooled at a slightly greater rate than the vesicular lavas outside. The reason for the quicker rate of cooling is not apparent, but may perhaps be due to the lava having reached a generally lower temperature by the time the rims started solidifying.

What then is the explanation of the whole series of phenomena?

The significance of the craterlets.

Speaking in the most general way the evidence shows that these hollows represent the vents for the escape of steam and hot gases and sometimes, perhaps, lava from the interior of the flow after the crust had solidified. But if we try to form a detailed picture of

the sequence of events difficulties arise. If the vents had vertical walls like a pipe, how could the rock have been kept liquid long enough for it to lose its contained gases without flowing back into the interior? The secret is perhaps revealed by the existence, here and there on the surface of the flow, of flattish patches of non-vesicular lava like that of the rims. These, taken in conjunction with the basin shape of at least one of the hollows—no. 3—and the not uncommon radial columnar jointing of the rims, leads to the following detailed explanation, which, though in some respects unsatisfactory, seems to fit practically all the facts.

It seems evident, both from *à priori* reasoning, and from all that has been observed in connection with lava flows that when a lava is poured out at the surface, the first parts to solidify are the lowermost layers at their contact with the underlying cool rock, and the upper surface due to the chilling effect of the atmosphere. The interior still remains liquid. Like the lava that gave rise to the vesicular surface, the interior liquid lava contains dissolved gases and water, and under favourable circumstances it is conceivable that the liquid interior might maintain open vents in the otherwise solid surface for the escape of these gases. This would mean a protrusion, from below, upwards into the solid crust, of domes of liquid lava, each with an orifice or vent at the surface. Probably the vent could tap the lava only for a certain distance downwards owing to the viscosity of the lava. With increasing viscosity of the lava as it cooled it became more difficult for the gases to escape, so that finally a bubble from 3 to 20 feet across, composed of plastic lava, was formed across the mouth of the vent. The last portion to solidify, of the material served by the vents, was, perhaps, the centre immediately below the vent, and the central plug of vesicular lava in many of the craterlets represents this material.

The 'mineralising' action of steam and other gases on magmas is well known, and it is possible that the lava, once its dissolved gases had escaped, was able to solidify at a higher temperature than was otherwise possible whilst the gases were still present. As the molten pool of lava cooled with loss of heat and dissolved gases, it took on a columnar radiate structure.

What we now see at the surface in the Kulbehra is, according to this explanation, the very surface of the flow suffering in places from the effects of slight differential erosion of the top few feet. The rim of the craterlet, then, doubtless represents the actual

edge of the burst bubble in some cases, whilst in others denudation has cut down to a slightly lower level. Where we see now a layer of non-vesicular rock resting on vesicular rock as in no. 17 (see page 133), we are probably looking at the denuded base of a very small local pool in the vesicular crust. Of course, the remainder of the flow below the crustal layer of vesicular lava and craterlets probably remained liquid or plastic, at least in part, after the solidification of the rock in the vents. The case of no. 11, where the rim is breached by lava flowing from outside into the interior, is explicable as due to lava derived from the still-molten portions of the flow (see Plate 10, fig. 2).

On the basis of the explanation given above—as, indeed, of any likely one—we might expect to find craterlets at the surface of any thick lava flow. The fact that we do not indicates, perhaps, that some special combination of temperature gradient and percentage of dissolved gases happens to favour the formation of these liquid crustal pools with subsequent solidification in the manner indicated.

Choice of name.

Throughout this paper we have applied to these curious hollows the term *craterlet*, which seems to be the most suitable designation. For in view of the foregoing account, they can hardly be regarded merely as huge lava bubbles, or merely as steam vents, for it seems likely that small amounts of lava welled out of at least no. 3. On the other hand they cannot be regarded as true craters, because they served as vents only to the already-erupted lava flow on which they occur, and not as orifices for the extravasation of fresh lava from some underground source. They cannot, therefore, be termed, appropriately, either bubbles, solfataras, or craters, and we have consequently adopted the term *craterlet* in lieu of a better.

Radiate columns.

A radiate arrangement of columns in a basalt flow is occasionally seen in the Deccan Trap formation (see, *e.g.*, fig. 16, p. 258, Second Edition of the Manual of the Geology of India), and it may be suggested that in some cases such phenomena point to the maintenance of liquid pools in the flow after the main mass of the flow had solidified, the cooling of the pool taking place from the periphery inwards.

Before closing this section with a brief account of each craterlet, it will be interesting to enquire whether these phenomena can be matched with any previously described, either in India or abroad.

Lonar Lake.

The only crateriform hollow hitherto discovered in the Deccan Trap formation is the remarkable circular depression in Berar known as the Lonar Lake. This lake occupies a crateriform depression in basaltic lavas of the Deccan Trap, which dip gently away from the lake in all directions. The depression is circular, and measures 1¼ miles across at the top of the encircling walls; it is 300 feet deep with an even bottom. The lake is very shallow, the water being nowhere more than 2 feet deep at the time of Mr. T. D. LaTouche's visit in March 1910.[1] Below the water is silt resting upon solid rock, which is only 30 feet from the surface of the water at its lowest, according to Lieutenant-Colonel R. G. Smythe writing in 1884.[2] The true nature of this hollow is not yet known. According to W. T. Blanford[3] and R. D. Oldham[4] it is an explosion crater, the detritus of which has since been washed away; but according to T. D. LaTouche, the latest writer on this lake, who revives and improves an old hypothesis advanced by Prof. A. B. Orlebar in 1839,[5] the depression is the result of the formation of a kind of 'blister,' supported either by steam or vapour under pressure or by a laccolitic intrusion of molten rock. It is supposed that the steam or lava escaped through a lateral opening leaving the centre of the dome unsupported, which then, after the formation of a circular fissure, sank back into the cavity.[6] Apart from the great size of the Lonar Lake compared with our craterlets, it is obvious that there is a radical difference, whatever be the true cause of each. The Lonar depression, being 300 feet deep, must traverse more than one lava flow, probably at least 3 or 4, assuming the flows of this part of India to have the same general thickness as in the Satpuras; whilst the Shikarpur craterlets characterise the surface, merely, of a single flow.

[1] *Rec. Geol. Surv., Ind.*, XLI, pp. 266—275, (1912).
[2] *Loc. cit.*, p. 271.
[3] *Op. cit.*, I, p. 62, (1870).
[4] *Op. cit.*, XXXIV, p. 147, (1906).
[5] *Trans. Bombay, Geogr. Soc.*, II, p. 35.
[6] It is difficult to see that this procedure would be followed, with steam or vapour as the lifting agent; for on the escape of the steam or vapour the whole of the cover should fall back to its original position. But if the lifting agent was a laccolite of lava, then the truth, or otherwise, of Mr. La Touche's hypothesis should be demonstrable by means of a careful survey, on the lines of that described in this paper, of the immediately surrounding country. The lava flow *c* of figure 4, p. 274 of LaTouche's paper, or its dyke connection, would then be detectable with certainty, if the hypothesis be true. It should be noted, however, that W. T. Blanford (*l.c.*) states '*No dykes whatever were observed*' (Blanford's italics).

Parasitic cones of Etna, Vesuvius Galapagos Isles, Réunion, and Kilauea.

It is doubtful if any hollows in the surfaces of lava flows exactly similar to these 'craterlets' have hitherto been described in any of the volcanic areas of the world. They are apparently quite lacking in the lavas of the Western Isles of Scotland, and we have been unable to find any description of such phenomena in the great basaltic flows of Idaho and other parts of the north-western parts of the United States. When we leave the products of fissure eruptions, to which belong the lavas of the Deccan, the Western Isles of Scotland, and the plains of Idaho, and consider the products of central eruptions, we have, of course, the secondary cones so common on some volcanoes, particularly on the flanks of Etna; but such cones differ essentially from the Indian craterlets in the fact that they are built up of fragmental materials brought up from below the ash-beds or lava flows on which they rest. Perhaps the nearest analogue to the Indian craterlets is to be found in the miniature parasitic cones which 'are often formed on lava-streams by the discharge of steam and gases from the cooling lava. They vary in dimensions from a few feet to a few yards in height, and are common on most volcanoes.' [1] Many such small cones (*spiracles* or '*boccas*') were observed by Poulett Scrope on the surface of the Vesuvian lava current of 1822 [2]: whilst Darwin,[3] describing the lavas of Chatham Island in the Galapagos Isles, writes 'here and there the lava, whilst soft, has been blown into great bubbles; and in other parts, the tops of caverns similarly formed have fallen in, leaving circular pits with steep sides.'

Another somewhat similar case occurs in the Island of Réunion; it is carefully described by Charles Vélain on pages 100 to 104, and illustrated in figures 14, 15, 16, and in Plate 11, of 'Description géologique de la presqu'île d'Aden de l'île de la Réunion, etc.,' (1878). He writes (p. 100):—

> 'D'autres fois, des dégagements considérables de gaz et de vapeurs ont soulevé la masse visqueuse, de manière à laisser au-dessous d'elle de grandes cavités, qui sont restées vides après la solidification.'

One of the best examples of these blisters (*ampoules*) seen by Vélain forms a remarkable grotto, known as the *caverne de Rosemond*, or *la Chapelle*, hung with stalactites of lava. And near this

1 Prestwich's 'Geology, Chemical, Physical, and Stratigraphical,' Vol. I, p. 196, (1886).
2 'Volcanos,' 2nd Edit., p. 80, (1872).
3 'A Naturalist's Voyage,' p. 359, New Edit., (1890). Also see 'Geological Observations on the Volcanic Islands, etc.,' p. 116, 2nd Edit., (1876).

grotto are several craters lacking the conical superstructures, and consisting of simple openings 30 to 40 metres across and 7 to 8 metres deep. The smallest of these is shown in Plate 11 of Vélain's work and bears a certain resemblance to the Indian craterlets, but is much more picturesque owing to cascades of lava from a subsequent flow. These lavas of Réunion are very viscous and of basic composition, and it is doubtless this viscosity that has led to the formation of the crateriform openings, which are regarded as vents for steam and scoriæ.

Reference may be made to still another case, namely Kilauea in the Sandwich Islands. In an account, based on that of J. D. Dana, of the 1840 eruption of a flow of basalt extending for 11 miles from the place of issue to the sea, Professor Bonney writes [1] :—

> 'Here and there on the surface of the floor were miniature cones a few yards in height, out of which lavas had spouted for a while after the stream had flowed on.'

This section may appropriately be closed with a brief description of each craterlet.

Details of the Craterlets.

The craterlets were examined in November, when there was still a fair amount of water in the river; doubtless they are better exposed later in the dry season. The measurements of the craterlets are internal measurements :—

No. 1.—This is 9′ 2″ by 8′, internal measurements, with its long axis directed N. 10° E. It had a circular rim immersed in the river except on the northern edge. The sides slope inwards, the depth of water inside being 22.″

No. 2.—This is 6′ 10″ in diameter and circular. The west wall was submerged, with the east edge projecting a few inches above water. Depth of water inside 16″.

No. 3.—(See Plate 11).—This is the best craterlet of all. It is 13′ by 12′ 9″. Measuring from the N. E. edge it is 5 feet deep, but only 3 feet on the opposite side where the wall is lower. The wall tends to be columnar at right angles to the circumference. The inner 7″ to 8″ of the columns consists of compact non-vesicular trap, passing outwards through the remainder of the columns (1′ to 2′ long) from finely to coarsely vesicular rock,

[1] 'Volcanoes,' p. 57, (1912).

The sides of the craterlet are nearly vertical, sloping inwards slightly. It contained $1\frac{1}{2}$ feet of water in the middle, so that the nature of the rock there could not be examined. Some of the vesicular trap on the banks of the craterlet might easily have been erupted from the interior.

No. 3A.—This is of very irregular shape, 12′ 3″ by 7′ 9″, with a partition, as shown in fig. 1, dividing it into 2 cells. The material composing the walls and partition is hard and yet contains small vesicles, but is quite distinct from the coarsely vesicular rock outside. The wall varies from 6″ to 2′ 5″ in thickness.

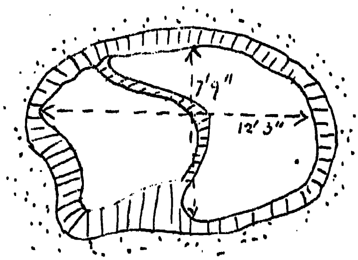


FIG. 1. CRATERLET NO. 3A.

No. 4.—(See Plate 12.) This, nearly the smallest craterlet, is also the most perfect. It is represented in plan in fig. 2, and is only 4′ 3″ by 3′ 9″ in internal diameter. The rim is about 1 foot thick and instead of dipping inwards seems to dip outwards under the external

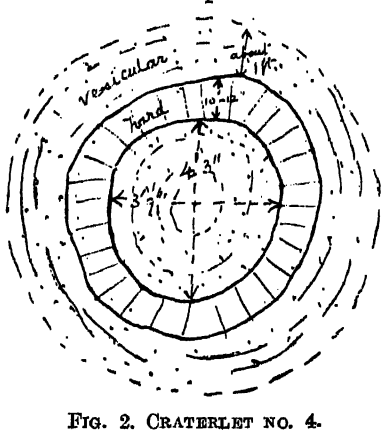


FIG. 2. CRATERLET NO. 4.

vesicular lava. This suggests that it may be increasing in diameter downwards, as one would expect in some cases. The interior is filled with vesicular lava.

No. 5.—This is 23′ by 18′ with its long axis N. 30° E. It lacks the usual clean-cut outline due to hard walls, and possesses instead sides of vesicular basalt, which at the edge itself contains small vesicles, but away from the edge is coarsely vesicular, containing amygdales of quartz, chalcedony, and calcite, usually averaging ½ inch in diameter. It contained 2 feet of water, whilst the bank rose another 3 feet, giving a total depth of 5 feet.

No. 5A.—This is not a proper craterlet, and serves to show the relationship between the true craterlets and more normal cooling phenomena. It is an oval depression with its long axis north and south, and is merely a jointing effect in the amygdaloid, of which it is entirely composed. Through it runs in both directions along a N. 8° W. line a long master cooling crack. Parallel to this is another similar furrow, and each crack is marked by a series of pools. Fig. 3 shows such a

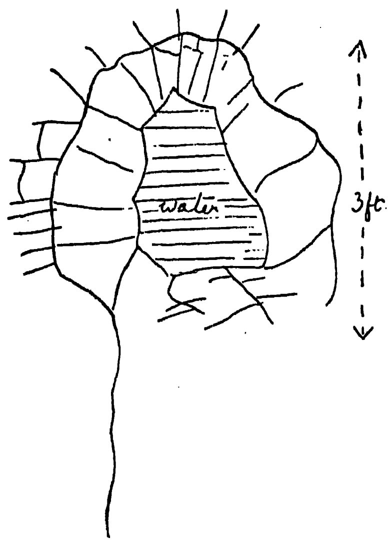


FIG 3.

pool, the hollow being evidently a jointing phenomenon produced by the cooling of the surface.

No. 6.—This craterlet was almost entirely submerged and not amenable to examination. It is 3′ in internal and 6′ in external diameter.

No. 7.—It has an internal diameter of 4′ 9″ in a N. W. direction. It has the usual hard rim, 6″ to 12″ thick, with vesicular trap both inside and outside; but, the rim is incomplete, forming a rough semicircle.

No. 8.—This craterlet, 16′ across in a W. N. W. direction, was almost entirely submerged, a few feet of the eastern part of the rim being visible. The rim, which slopes inwards, shows only 3″ to 4″ of the hard trap, passing rapidly outwards through finely vesicular to coarsely vesicular lava.

No. 8A.—This is 5′ in diameter, in the shape of a horseshoe, with the opening of the horseshoe directed to the S. E. The whole of the rock is vesicular, the sides sloping gently upwards in saucer fashion for 1 to 1½ feet.

No. 9.—(See Plate 13.) This fort-like craterlet, which is 8′ by 6′ (long axis N. E.), has the most marked wall of all. It is over 3′ high outside on the N. E. side, and about 3′ feet deep inside. The wall varies from 1′ to 4′ thick, but is not compact in its entire thickness, there being vesicular patches here and there. Inside there is also vesicular trap.

No. 10.—(See Plate 10, fig. 1.) It is a circle 16′ in diameter, lying in water, with its wall breached in two places. The wall varies from a few inches to 2′ thick, and passes into vesicular trap outside. It seems to slope inwards.

No. 11.—(See Plate 10, fig. 2.) This craterlet is of ovoid shape, 15′ by 11′, with its long axis in a W. by N. direction. The wall varies from 1¼′ to 2½′ thick, and appears to be breached on two opposite sides by compact lava, similar to the material of the rims, flowing into the craterlet from outside (see fig. 4). For a possible explanation of this see page 125. Inside

the wall at the western end there is some coarsely vesicular trap.

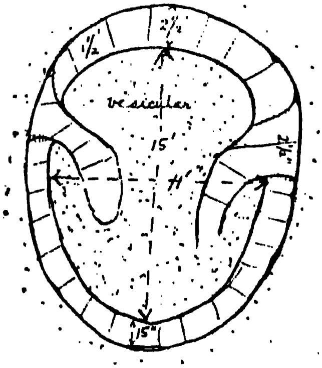


FIG. 4.

No. 12.—(See Plate 14.) This craterlet is 8′ 8″ by 7′ 8″ (long axis W. N. W.), and is circular with a central plug. The rim varies from 13″ to 22″ in thickness, and like the plug, is composed of compact trap, which, however, is in both cases slightly vesicular, the plug being less vesicular than the rim. Between the rim and the plug is an annular depression, occupied, where rock is visible, by more amygdular rock, similar to that immediately outside the craterlet. There are also small patches of softish amygdaloidal rock resting on the top of the rim (see fig. 5).

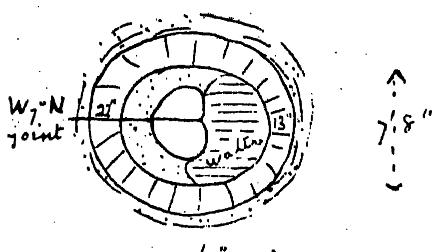


FIG. 5.

No. 13.—The submerged semi-circular rim is 13″ across the horns in a N. 80° E. direction, the opening being

directed towards the west. In places the edge of the rim just reached the surface of the water.

No. 14.—This is the craterlet that first attracted attention to these phenomena. It measures 9′ 4″ (S. 10° W.) by 8′ 1″ external diameter, and has a wall of non-vesicular rock varying from 2 to 3 feet in thickness: this rim rises only a few inches to 1′ 3″ above the central hollow, and only a few inches above the external basalt. The central slightly eccentric hollow contains loose stones.

No. 15.—This is a rough circle of about 6′ internal diameter, with a rim 2½ to 3¾ feet thick, composed of hard, though slightly vesicular, basalt, the central portions of the rim being more vesicular than the two peripheries. A little soft vesicular trap is seen attached to the interior, as well as outside.

No. 16.—This is an almost completely submerged circle, 13′ in diameter, close to the west bank of the river.

No. 17.—This is a small cap of hard black trap about 3½ by 2 feet in diameter resting on amygdaloid. A suggestion as to its nature is advanced on page 125.

No. 18.—Nearly circular, about 4′ internal diameter, with walls about 2′ thick, and passing into amygdaloid both outside and inside.

No. 19.—This, the most northern of the craterlets, is merely the remains of a small one, with thick walls, the surrounding rock being fairly compact also, with veinlets of chalcedony.

VIII. SUMMARY.

1. This paper states the results of an attempt to map in detail, flow by flow, a selected area of Deccan Trap lavas of about 65 square miles in extent lying immediately to the south of Chhindwara, in the Chhindwara district, Central Provinces, the chief village situated on these lavas being Linga. This paper does not give the microscopical and chemical characters of the lavas, which, it is hoped, will be described later.

2. The number of flows detected is five, numbered from below upwards, 1, 2A, 2, 3, and 4. Their average thickness is about 60 feet, giving a total thickness of about 300 feet.

3. The basal flow rests either directly on Archæan granites and gneisses, or is separated therefrom only by a small thickness of calcified and silicified gneisses (so-called 'Lameta').

4. These flows are probably not the basal flows of this neighbourhood only, but are probably at or close to the base of the entire Deccan Trap succession, at least as exposed at the surface.

5. Each of the flows is of basaltic composition, and is composed typically of labradorite, augite, and magnetite, with interstitial glass, usually in but small quantity, and with sometimes a little olivine, which is particularly characteristic of flows 1 and 2. There is a tendency for the olivine to be more abundant at the base, as is most evident in flow 2; this is probably due to gravitative differentiation during cooling.

6. Flow 3 is remarkable in containing in many places abundant shot-like spherules of glassy aspect, which are pale golden when freshly broken, but, on exposure, rapidly change colour to ruby-red or black. This mineral is probably identical with or closely allied to the chlorophæite of the Western Isles of Scotland, which exhibits the same remarkable colour change, and is found in the basic lavas termed mugearite by Harker.

7. Although each flow has its own individuality, yet there is a tendency towards conformity to a standard succession of textures and structures on passing from the base to the surface of each, in consequence of which it is often impossible to refer a given exposure to its proper flow without tracing its stratigraphical connection with exposures of known position in the series.

8. The type flow towards which all tend to conform shows vesicular basalt at the base, passing up into non-vesicular columnar basalt; this becomes coarser and coarser in grain, until toward the centre of the flow the rock may be a coarse-grained dolerite, above which it becomes basaltic again, and finally vesicular and amygdaloidal. Dolerites are best developed in flows 1 and 2.

9. The detailed mapping has proved that these dolerites belong to surface flows, so that they differ from the dolerites of Skye, which according to Harker's interpretation are sills intrusive in a series of extrusive basalt flows.

10. Each flow is separated from the overlying and underlying flows not only by vesicular surfaces, but also usually by an Intertrappean horizon of small thickness, composed either of fresh-water fossiliferous sediment, or of 'green-earth,' or of both together. It

is the existence of these Intertrappean horizons, that has rendered possible the separate mapping of the flows.

11. The green-earth has been formed by the alteration of the base of each flow and cannot thus be strictly regarded as Intertrappean; the composition and exact mode of formation of this product will, it is hoped, be described subsequently.

12. The general aspect of the Linga series of flows suggests horizontality, but detailed mapping combined with a careful use of the aneroid barometer, has shown that the flows are no longer in the exact position in which they cooled. They have been folded, indeed, into a parallel series of gentle anticlines and synclines striking W. by N. and E. by S., with a slight pitch to the E. by S. In addition to the folds, evidence has been obtained of the existence of three small faults with the same general strike. The most important of these, the Paunari fault, has a downthrow to the north of about 50 feet.

13. Since this E. by S. direction is parallel to the direction of foliation of the Archæan gneisses in this neighbourhood, it is suggested that the compressive stresses of post-Trappean times to which the folding is due may represent a feeble repetition or echo of those applied so much more intensely in the far-off Archæan times.

14. The onyx geodes in the surface of flow no. 1 in the Baradoi Nala were found to dip at slightly more than 1° to the E. S. E. This is considerably greater than the general dip of the flows to the S. E., which is only 35 feet to the mile. The dip recorded in the geodes is consequently thought to be a local tectonic result, whilst the general dip, it is suggested, may represent the original flow dip of the lavas, but is possibly due to a general slight tilt imparted to the lavas at the same time as the folding.

15. A local sag with a N.—S. alignment, detected in the traps near the Kulbehra river, is thought to mark the position of a pre-Trappean depression in the underlying Archæan surface, probably the direct ancestor of the Kulbehra itself. The present-day tributaries of the Kulbehra tend to be aligned in an E. by S. and W. by N. direction, *i.e.*, parallel to the axes of folding; but as the axes of folding are probably parallel to the direction of foliation of the underlying gneisses, and therefore, probably, to the surface features of those gneisses on the pre-trappean peneplain, it is suggested that the flows may have solidified with slight depressions on their surfaces parallel to the underlying valleys, which would

ined the position of fresh drainage lines on the new cally above the old ones. The post-Trappean folding being also parallel to the foliation of the gneisses would ccentuated and confirmed the directions of these drain- [t is thus suggested that in the Kulbehra and its tri- may be looking at a generalised reproduction of the tem of this area in pre-Trappean times.

vesicular surface of flow no. 1 in the Kulbehra river karpur is rendered remarkable by a series of some ollows, with rims of non-vesicular lava. These hollows to 20 feet in diameter, and are from 1 to 3 or even They are regarded as representing the vents for the eam and hot gases, and sometimes, perhaps, of lava, lten pools within the interior of an otherwise solidi- w. For want of a better term they are designated 'e have been unable to find any accounts of the exist- sely similar structures elsewhere in the world.

LIST OF PLATES.

A NOTE ON THE IRON ORE DEPOSITS OF TWINNGÉ, NORTHERN SHAN STATES. BY J. COGGIN BROWN, M.Sc., F.G.S., M.I.M.E., *Assistant Superintendent, Geological Survey of India.*

Locality.

THE deposits occur near Twinngé, approximately 1,000 yards north-north-west of a point on the railway 2 miles north-east of Thondaung (Lat. 21° 56′ 30″ : Long. 96° 24′ 30″), a station on the Lashio branch of the Burma Railways, between Mandalay and Maymyo (see Burma Surveys map, old no. 243 ; new no. 93 C-5).

History.

Like other mineral deposits which have attained commercial importance in this part of the world, the Twinngé iron ores did not escape the attention of the ancient miners, traces of whose activities were still visible a few years ago. The name "Thondaung," is Burmese and means "Iron Hill."

Geology of the area.

At Thondaung railway station the shaly limestones of the Nyaungbaw stage (Upper Ordovician) are visible, with an easterly dip of about 20°. Continuing up the line towards Twinngé, they give place after a short distance, to the Zebingyi (Tentaculites) beds of the Upper Silurian, which in their turn are replaced by Plateau Limestone (Devonian ?). A fault then repeats the succession,—flaggy Nyaungbaw limestones, reddish shales with *Tentaculites elegans*, resting on the eroded surfaces of the former, and Plateau Limestone which marks the commencement of the main plateau stretching far to the east from this point. To the north of Twinngé, the thin band of Zebingyi beds is replaced by a broad belt of rocks belonging to the Naungkangyi series (Ordovician).

The area occupied by the mining lease is entirely within Plateau Limestone, with its characteristic forest, sterile red soil and stream-beds full of calcareous tufa. One of the most striking features of this formation, not only in the region under discussion, but everywhere over the hundreds of square miles across which it extends, is the mantle of red clay which covers it. Of a prevailing bright Indian red colour, this clay may attain depths

of 20 or 30 feet. Its origin is attributed to the accumulation under weathering of the insoluble matter in the limestone itself, and in the shale and clay bands which are sometimes interstratified with it. The clay contains little or no sandy matter, is stiff and tenacious in nature and is often full of pisolitic nodules of oxides of iron, ranging in size from small shot upwards. La Touche has compared it with the "terra rossa" of Istria and Dalmatia and thinks it may have been produced by a process of lateritisation, the difference between the final product and ordinary laterite being perhaps due to the absence of siliceous matter from the limestone.[1]

Occurrence of ore at Twinngé.

The Twinngé ores occur entirely in this red clay. The lease has an area of 1,630,000 square feet. 160,000 feet of this are occupied by limestone without any covering. The remaining 1,470,000 square feet contain ore-bearing clay. The deposit forms a low irregular hill, and the thickness of the overburden, a hard Indian red clay, which must be removed before the ore-bearing layer can be reached, ranges from nothing at the summit of the hill to 6 feet at its bottom.

The average probably lies between 2 and 3 feet. Underneath this non-productive overburden is a band of deep red clay which is assumed to have a thickness of 3 feet. It is not always possible to measure the exact thickness of this band because the pits by which the ore is extracted seldom reach the base of it. In one working which touched limestone the band measured from 2 to 3 feet in thickness.

According to a report on the deposit by Mr. M. H. Loveman, Economic Geologist to the Burma Mines Co., Ltd., courteously furnished me by Mr. C. H. Macnutt, Resident Manager,—to both of whom I am greatly indebted,—"In 29 pits examined the average thickness was 2 feet, and in all but 4 of these, the bottom was still in ore. It appears safe to assume an average thickness of 3 feet over the whole deposit. This conclusion is strengthened by the 4 pits in which limestone was reached. In these the thickness of ore was 18, 24, 36 and 48 inches, respectively. In the first case the pit is on the extreme edge of the ore and should not be considered an average sample." Assuming then an average thickness of 3 feet, which I consider to be correct, and estimating it to contain 50% by volume in iron oxides, which I regard as rather a conservative figure, Mr. Loveman, reckoning 8 cubic feet to the ton for

[1] T. D. La Touche, Geology of the Northern Shan States. *Mem., Geol. Surv. Ind.*, Vol. XXXIX, Pt. 2, p. 322.

iron oxides, shows that there were originally 275,625 tons of ore in the proven area of the lease. Of these some 50,000 tons had been removed up to March 1914, leaving at that time 225,000 tons approximately. Further quantities have been removed since then. Occasionally, thin layers of a hard red clay, a few inches thick, separate the ore-bearing horizon from the limestone below. The ore occurs in rounded grains, pebbles and masses, ranging in size from peas to huge boulders several feet in diameter and weighing many tons. These are not cemented together or very firmly embedded in the clay which surrounds them, neither do they form a continuous layer. Figure 1, is a generalised vertical section showing the mode of occurrence of the ore. Segregation into rounded mammillated masses with a water-worn appearance is of course typical of the type of ore deposit

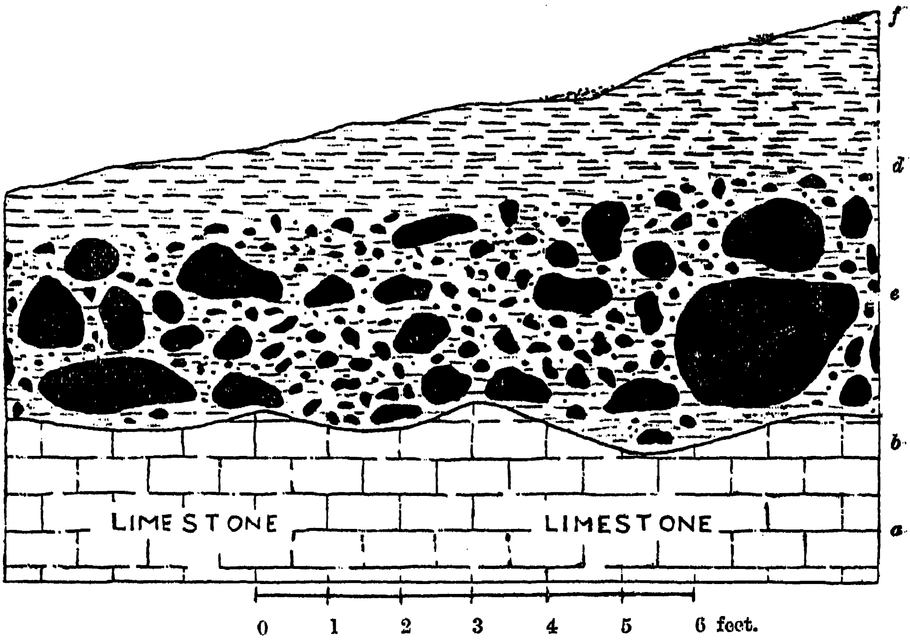


Fig. 1.—Generalised vertical section showing mode of occurrence of the iron ores of Twinngé, Northern Shan States.

a = Plateau Limestone.

b = Hard red clay.

c = Deep red clay with iron-ore.

d = Indian red clay or Plateau Earth.

f = Patches of ironstone gravel.

to which the Twinngé one belongs. On the outside these masses usually exhibit a light brown polish possibly a thin limonite skin. When broken open they are black or dark brownish-black with numerous very irregular reddish patches. The ores apparently consist of mixtures of limonite and hematite with, perhaps, mixtures of various colloidal hydroxides of iron. The average assays of the material delivered from Twinngé from September to December 1914 are as follows (the figures were kindly supplied by Mr. Macnutt):

	Insoluble %	Fe %	Al_2O_3 %
	10·2	56·3	3·4
with a range of —			
minimum . . .	7·4	51·7	1·8
maximum . .	14·4	59·2	5·7

The average assays from January to March 1915 were as follows :—

	6·4	60·1	3·4
with a range of —			
minimum . . .	3·0	55·3	2·0
maximum . .	12·1	62·7	5·4

Other similar deposits exist in the immediate neighbourhood. The surface of the ground shows the same type of light brown ferruginous gravel and larger pieces of iron ore. In more distant parts of the Shan plateau they will also be discovered when carefully searched for. Recently I have noticed the same indications between the villages of Wetwin and Padaukpin and also a few miles south of the latter locality, though whether the ores exist here in paying quantities or not has still to be determined.

Origin.

These iron ores are undoubtedly of residuary origin. It is well known that only a small part of the iron is carried away in solution during the ordinary processes of weathering, but at first sight, it appears difficult to understand how such enormous quantities of clay and iron ore have been concentrated from the Plateau Limestone, which as a rule contains low ferric oxide values and is only high in insoluble matter in exceptional cases. The dolomite at Twinngé does not differ in appearance and structure from typical material found elsewhere on the plateau. In seven analyses by the late T. R. Blyth (quoted by La Touche [1]), the oxides of iron and aluminium

[1] La Touche, *loc. cit.*, p. 188.

together only average 0·76%, while the insoluble residue of the same rocks averages as low as 1·09%.

But the Shan plateau seems to have permanently emerged from the sea in later Mezozoic times, and if the degradation of the strata of which it is built up has been proceeding since even later times than this, the removal of soluble constituents and concentration of the insoluble ones must have been enormous. The chemical processes which have resulted in the formation, in a subtropical climate, of a red ferruginous clay, containing extensive iron ore beds and very little if any calcareous matter, from very pure dolomites containing small amounts of iron and insoluble matter, are certainly of more than ordinary interest.

Methods of working.

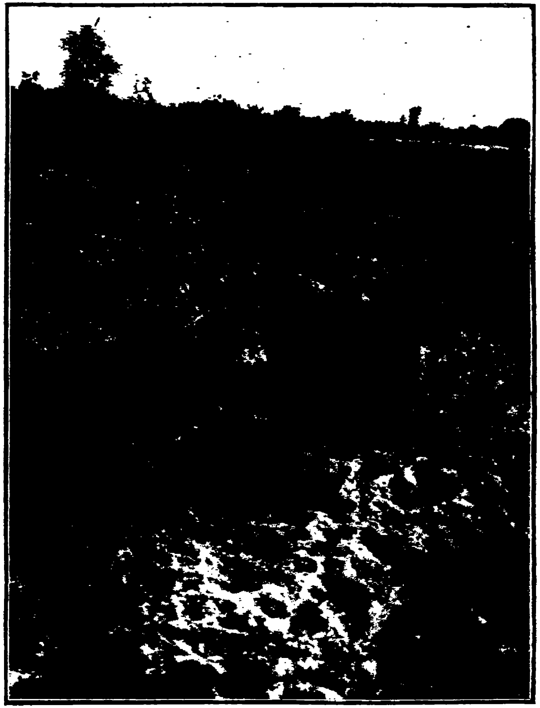
The proper method of exploiting such a deposit would be to start at the bottom of the slopes and remove the whole thickness of overburden and ore. Unfortunately this has not been done up to the present time, though I understand that it is to be adopted shortly. At present the native method of working consists in digging pits and trenches in a haphazard fashion on any position where the miner thinks he will obtain good ore. Again, the bottom layer of ore is in most cases left in the holes to be afterwards buried again under waste overburden from above. It is doubtful whether it will ever prove profitable to rehandle this. The large boulders of ore are also untouched at present.

After breaking into convenient sizes the ore is carried by carts to a siding where it is loaded into trucks and railed to Nam Tu. Here it is used as a flux in the local lead-smelting industry.

Photographs by L. L. Fermor.

FIG 1.—TUFA CONGLOMERATE WITH TRAP PEBBLES AND OVERLYING GRIT.

Kulbehra River near Nonia.



G. S. I Calcutta.

FIG. 2.—AMYGDALOIDAL BASALT SURFACE WITH TUFA VEINLETS.

Kulbehra River near Nonia.

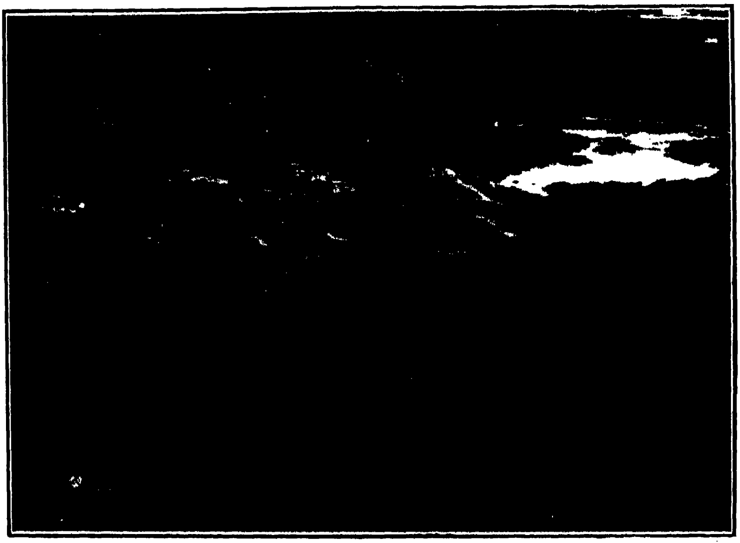


FIG. 1.—VESICULAR FISSURED SURFACE OF FLOW 1.

Shikarpur.

Photographs by L. L. Fermor *G. S. I. Calcutta.*

FIG. 2—TERRACES OF JOINTED DOLERITE OF FLOW 2.

Kulbehra River, near Paunari.

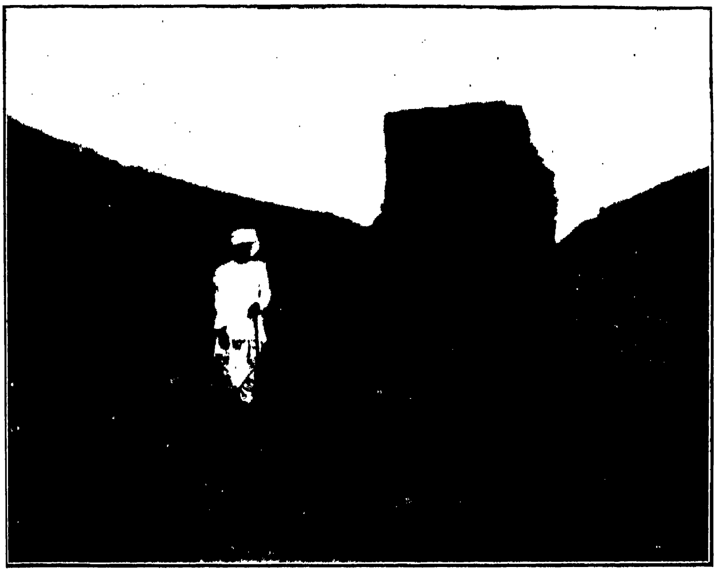


FIG. 1.—BASE OF FLOW 2 (FLAGGY DOLERITE) RESTING ON INTERTRAPPEAN CLAYS.
Railway cutting, Murmari.

Photographs by L. L. Fermor. *G. S. I. Calcutta.*

FIG. 2.—CONCAVE JOINTING IN BASAL DOLERITE OF FLOW 2.
Murmari.

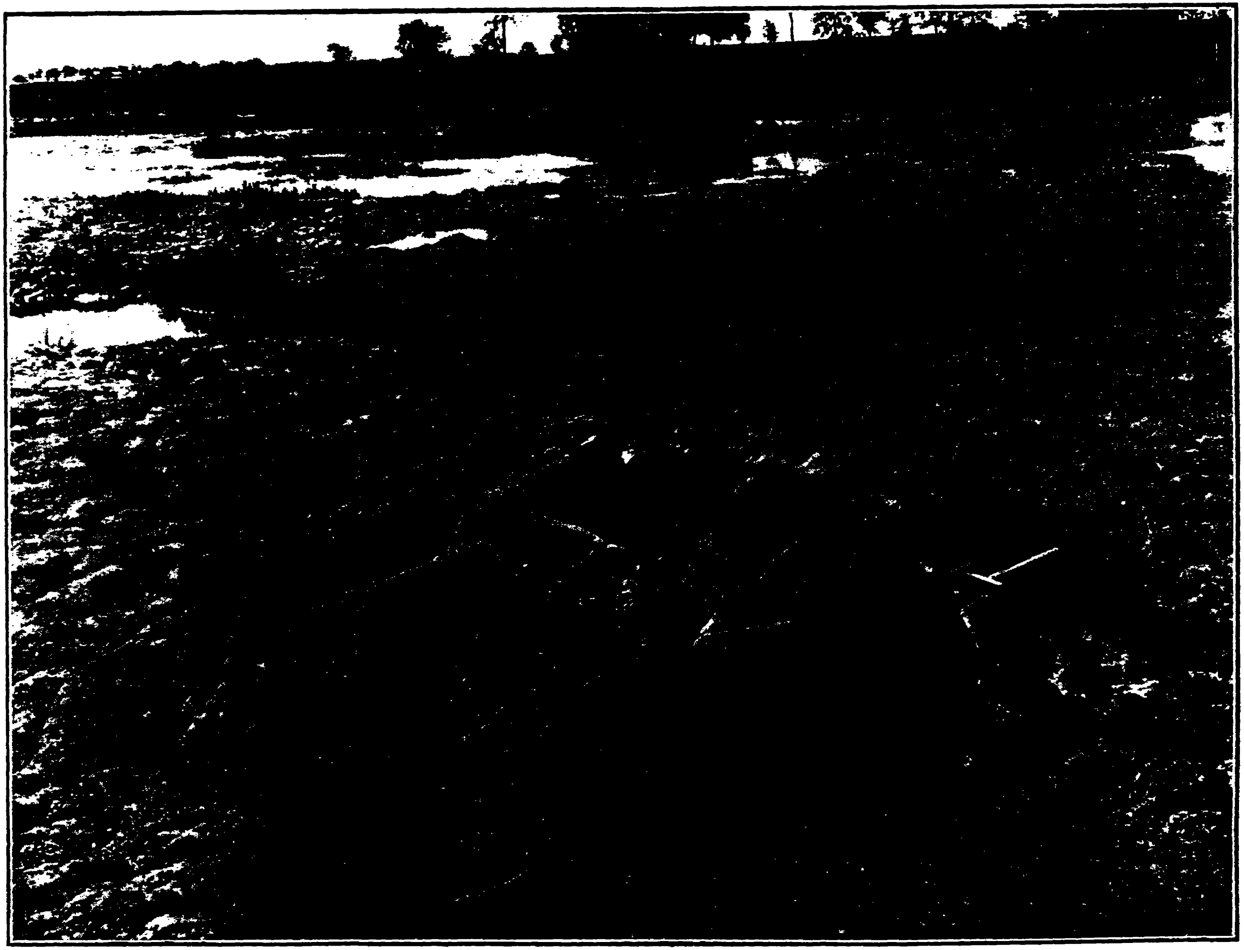
FIG. 1.—CRATERLET No. 10. Shikarpur.

Photographs by L. L. Fermor. *G. S. I. Calcutta.*

FIG. 2.—CRATERLET No. 11. Shikarpur.

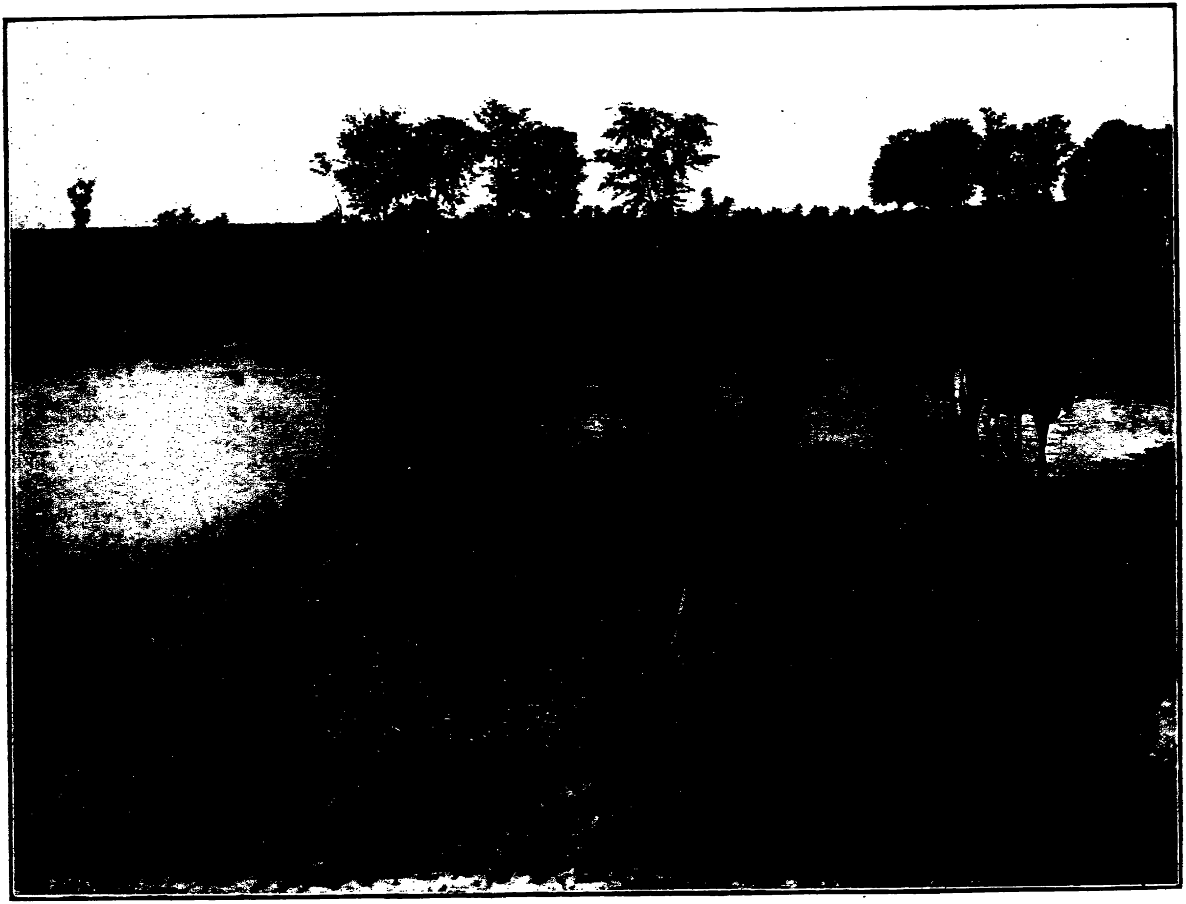
Photograph by L. L. Fermor *G. S. I. Calcutta.*

CRATERLET No. 3. Shikarpur.



Photograph by L. L. Fermor. *G. S. I. Calcutta.*

CRATERLET No. 4. Shikarpur.



Photograph by L. L. Fermor.

G. S. I. Calcutta.

CRATERLET No. 9. Shikarpur.

Photograph by L. L. Fermor. *G. S. I Calcutta.*

CRATERLET No. 12 Shikarpur.

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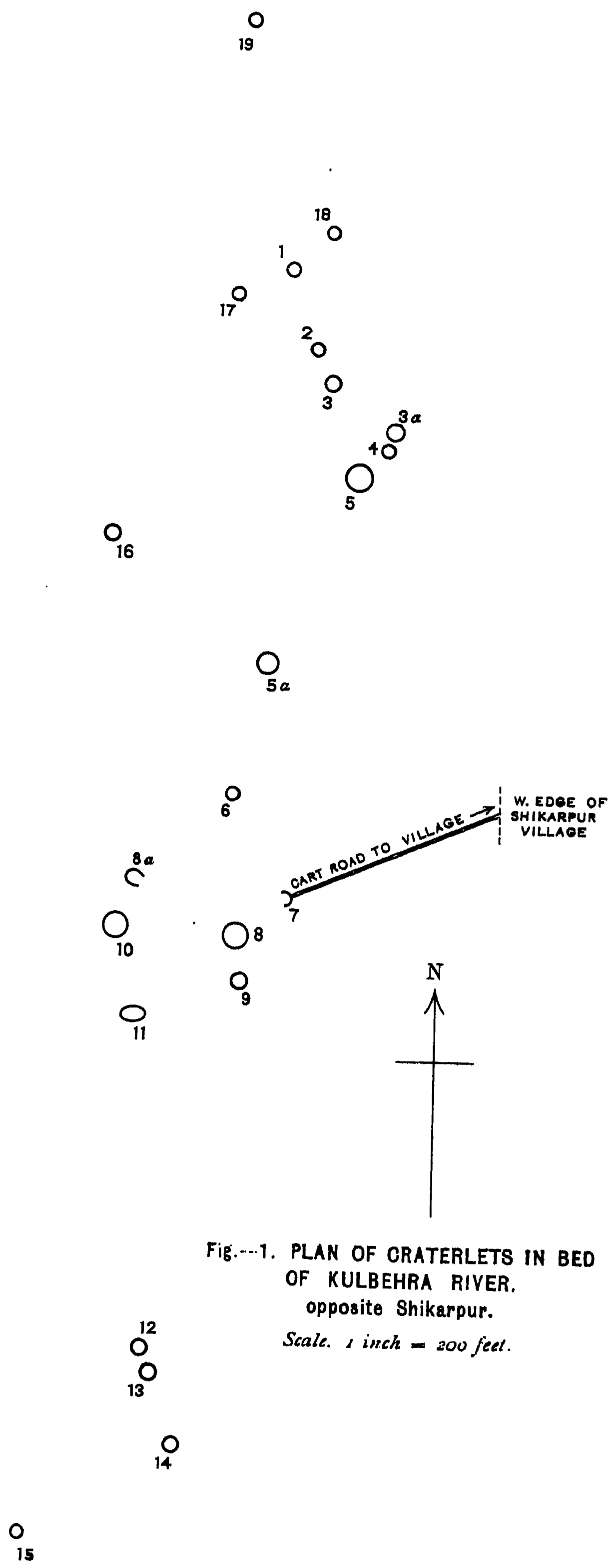


Fig.—1. PLAN OF CRATERLETS IN BED OF KULBEHRA RIVER, opposite Shikarpur.

Scale. 1 inch = 200 feet.

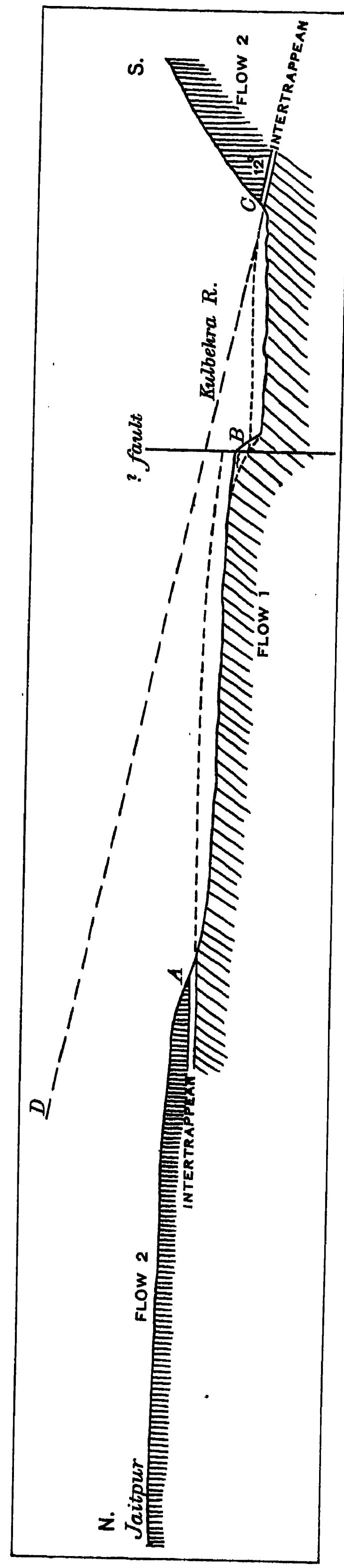


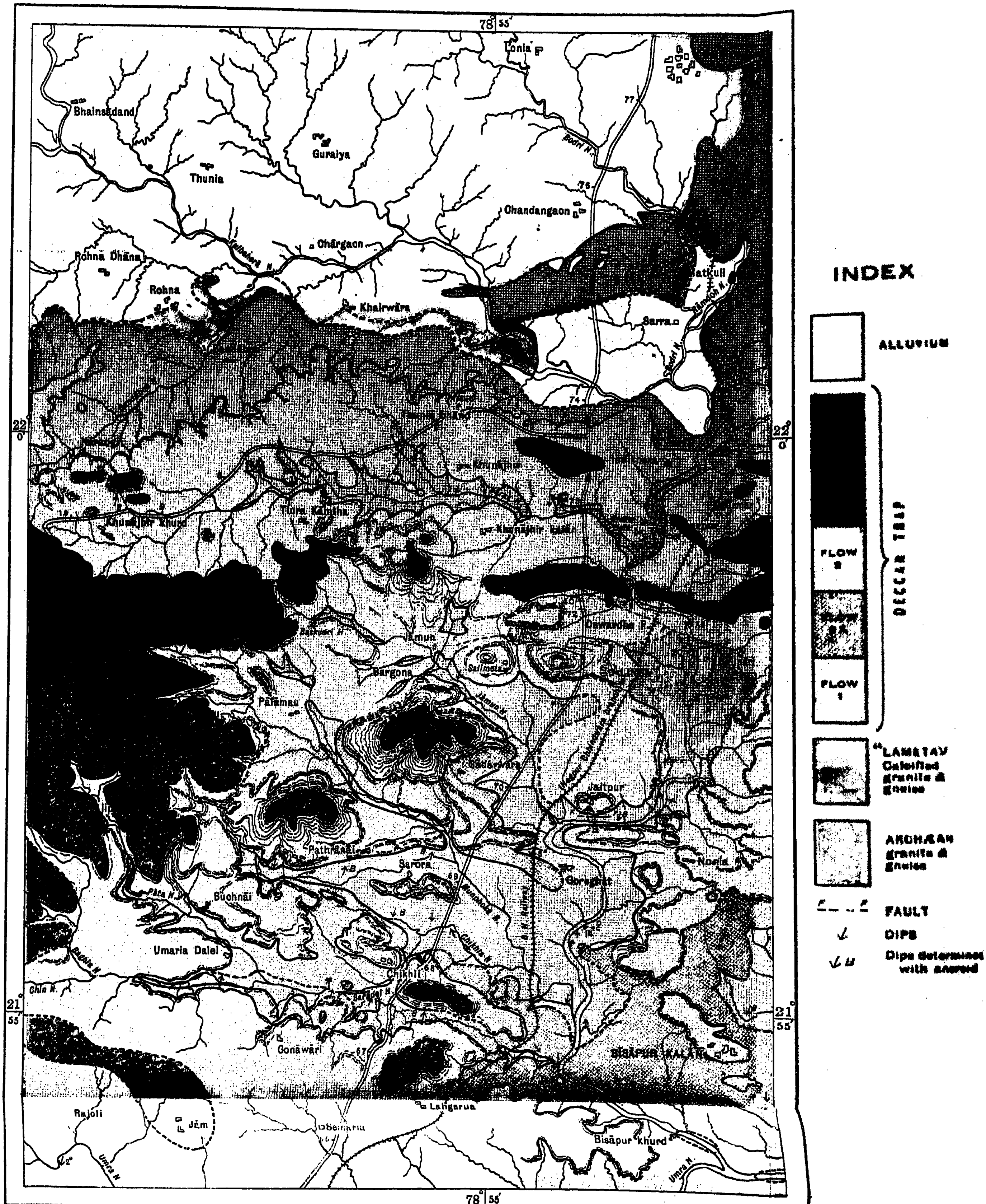
Fig.—2. SECTION ACROSS KULBEHRA RIVER AT JAITPUR.

Along line of section N. N. in Plate No. 10.

Scale, 1 inch = 133 feet.

Litho. G. S. I. Calcutta.

Records, Vol. XLVII, Pl. 16.



Geologically Surveyed by L. L. Fermor & C. S. Fox. G. S. I. Calcutta.

GEOLOGICAL MAP OF THE LINGA AREA, CHHINDW

Scale

0

RECORDS
OF
THE GEOLOGICAL SURVEY OF INDIA.

Part 3.] 1916. [August.

REGINALD COOKSEY BURTON.

Born, March 10th, 1890: Died of wounds, April 9th, 1916.

I greatly regret to have to record the death, on April 9th, of Mr. R. C. Burton, Assistant Superintendent, Geological Survey of India. Mr. Burton joined the Department in January 1912, and was posted to the Central Provinces, where, during his short period of service, he did admirable work in helping to solve the question of the origin of the calcareous gneisses which constitute such an important element of the Archæan group of that area. His investigations into the origin of the bauxite of Seoni and adjoining districts also gave evidence of marked ability and by his death the Geological Survey has lost one of the most promising, as well as one of the most popular, of its younger members.

Mr. Burton joined the Indian Army Reserve of Officers early in April, 1915, and after a short training in India, was attached to the 104th Rifles in Mesopotamia, where he died on April 9th from wounds received in action on the previous day. His loss is keenly felt by all his colleagues.

H. H. HAYDEN.

THE MINERAL PRODUCTION OF INDIA DURING 1915. BY H. H. HAYDEN, C.I.E., F.R.S., *Director, Geological Survey of India.*

CONTENTS.

I.—INTRODUCTION.

THE method of classification adopted in the first Review of Mineral Production published in these *Records* (Vol. XXXII), although admittedly not entirely satisfactory, is still the best that can be devised under present conditions. The methods of collecting the returns are becoming more precise every year and the machinery employed for the purpose more efficient. Hence the number of minerals included in Class I—for which approximately trustworthy annual returns are available—is gradually increasing, and it is hoped that before long the minerals of Class II—for which regularly recurring and full particulars cannot be procured—will be reduced to a very small number. In the case of minerals still exploited chiefly under primitive native methods and thus forming the basis of an industry carried on by a large number of persons each working independently and on a very small scale, the collection of reliable statistics is impossible, but the total error from year to year is not improbably approximately constant and the figures obtained may be accepted as a fairly reliable index to the general trend of the

industry. In the case of gold, the small native alluvial industry contributes such an insignificant portion to the total outturn that any error from this source may be regarded as negligible.

From Table 1 it will be seen that there has been an increase of 7 per cent. in the value of the total production over that of the previous year and this that value is now for the first time over 10 million pounds sterling. The increase in value is highly satisfactory in view of the many disturbing factors introduced by the war; and analysis of the figures shows that only a few of our industries have been affected adversely, while many of them have profited considerably by the higher prices realised during the past year.

TABLE 1.—*Total Value of Minerals for which Returns of Production are available for the years 1914 and 1915.*

Mineral.	1914.	1915.	Increase.	Decrease.	Variation per cent.
	£	£	£	£	
Coal	3,907,380	3,781,064	..	126,316	— 3·2
Gold	2,338,355	2,369,486	31,491	..	+ 1·3
Petroleum	958,565	1,256,803	298,238	..	+ 31·1
Manganese-ore (*a*)	877,264	929,546	52,282	..	+ 5·9
Salt (*b*)	483,289	660,254	176,965	..	+ 36·6
Saltpetre	272,462	373,891	101,429	..	+ 37·2
Lead and lead-ore	202,330	316,182	113,852	..	+ 56·2
Tungsten-ore	178,543	296,772	118,229	..	+66·2
Building materials and road metal	218,879	204,652	..	14,227	— 6·5
Mica (*c*)	237,310	183,947	..	53,363	— 22·5
Tin-ore and Tin	38,203	54,980	16,777	..	+ 43·9
Jadestone (*c*)	40,092	52,070	11,978	..	+ 29·9
Ruby, Sapphire and spinel	43,133	36,298	..	6,835	— 15·8
Monazite	41,411	33,238	..	8,173	— 19·7
Iron-ore	40,665	31,886	..	8,779	— 21·6
Silver	26,896	31,150	4,254	..	+ 15·8
Copper-ore	7,294	14,381	7,087	..	+ 97·2
Alum	4,649	4,393	..	256	— 5·5
Magnesite	557	3,973	3,416	..	+ 613·3
Clay	2,792	3,834	1,042	..	+ 37·3
Chromite	2,611	3,531	920	..	+ 35·2
Steatite	4,146	2,578	..	1,568	+ 37·8
Agate	175	1,019	844	..	+ 482·3

(*a*) Value *f. o. b.* at Indian ports.
(*b*) Prices without duty.
(*c*) Export values.

TABLE 1.—*Total value of Minerals for which Returns of Production are available for the years 1914 and 1915*—contd.

Mineral.	1914.	1915.	Increase.	Decrease.	Variation per cent.
	£	£	£	£	
Gypsum . . .	979	979	..	..	..
Diamond . . .	791	603	..	188	+'23·8
Ochre . . .	157	459	302	..	+ 192·4
Corundum . . .	447	277	..	170	— 38·0
Antimony . . .	4	236	232	..	..
Amber . . .	274	199	..	75	— 27·4
Zinc-ore . . .	10,762	174	..	10,588	— 98·4
Graphite . . .	..	158	158	..	..
Platinum . . .	213	100	..	113	— 53·0
Bauxite . . .	32	29	..	3	— 9·4
Garnet . . .	4,806	10	..	4,796	— 99·8
Samarskite . .	121	..	..	121	..
Asbestos . . .	23	..	..	23	..
Pitchblende . .	13	..	..	13	..
Triplite . . .	13	..	..	13	..
Total .	9,945,636	10,649,512	939,496	235,620	+ 7·0
			$\underbrace{\hphantom{939,496 \quad 235,620}}_{+\ 703,876}$		

Of the eight leading industries only one, namely coal, shows a decrease in the value of its output; at the same time, although the value of the outturn has decreased, the actual quantity produced has increased considerably and has risen from a little under 16½ million tons in the preceding year to over 17 million tons. This, of course, means that there has been a considerable fall in the price of coal, the direct cause being the scarcity of steamers and the consequent restriction of exports from Calcutta to other Indian ports. In the case of manganese-ore the relationship between the value and the amount of the output was exactly the reverse of that in the case of coal, for the actual output during the year 1915 was nearly 34 per cent. less than that of the preceding year, whereas the value of the exports was considerably higher; this again was due to the unnatural conditions introduced by the war. Similarly the action of the British Government in fixing the price of tungsten-ore at 55 shillings per unit has resulted in a proportionate increase in value of the output of wolfram. Another mineral of which the output was affected by

the war is mica, the trade in which was reduced by the restriction of exports to British countries and to a few neutrals. The export of zinc-ore also has practically ceased; in previous years the zinc concentrates from the Bawdwin mines had been sent to Germany and Belgium for reduction. The difficulty of obtaining graphite has caused a slight revival of attempts to work the deposits known to occur in the province of Bihar and Orissa. A small quantity of the material was extracted towards the end of the year under review; it is hoped that this will lead to a further revival of the industry. The garnet industry of Rajputana has been completely suspended owing to the absence of demand for cheap stones of that description.

Mineral concessions granted.

The number of licenses and leases granted during the year amounted to 307 as against 363 in the preceding year; 46 of these were mining leases and 261 prospecting licenses.

II.—MINERALS OF GROUP I.

Chromite.	Iron-ore.	Manganese-ore.	Platinum.	Saltpetre.
Coal.	Jadeite.	Mica.	Ruby, Sapphire and Spinel.	Silver.
Diamonds.	Lead-ore.	Monazite.	Salt.	Tin-ore.
Gold.	Magnesite.	Petroleum.		Tungsten-ore.
Graphite.				Zinc-ore

Chromite.

There was a fall amounting to 36 per cent. in the output of chromite in the year 1915 as compared with that of the previous year. The industry, however, has never been more than an insignificant one and owing to the difficulty of access, and distance of the mines from the sea-board, the production has always been very sensitive to any fluctuation in the market price of the ore. The chief producing countries during recent years have been New Caledonia, Rhodesia and Russia, the two former, however, largely preponderating, while the Indian contribution to the world's output is only about 2 per cent. of the total. During the past year shipments have been dependent on the cost of freight, and prices of chromite in the open market have been artificial and considerably higher than in normal times. There was a falling-off in the output both in Baluchistan and Mysore, but a slight increase in the Singhbhum district of Bihar and Orissa; the last-named locality has only become a producer within the last few years and conditions have not hitherto been sufficiently promising to encourage very energetic development. The only property that has been systematically exploited is in the hands of Messrs. Rae and Co., of Calcutta, to whom I am indebted for the information that they are at present (July, 1916) turning out about 200 tons per mensem, carrying from 48·79 to 51·20 per cent. $Cr_2 O_3$. The chromite occurs in serpentine, in layers varying from 1″ to 12″ in thickness; the layers, however, are very capricious both in size and in their manner of distribution. It has not been found possible to work profitably ore lying at a depth of more than 35 feet below the surface, since the ore-bodies are too small to repay the cost of much dead-work.

It is not likely that all the chromite deposits of Singhbhum have yet been discovered and it is possible that more promising ore-bodies will be found in the course of further prospecting operations. So far, however, there are no indications that India is likely to be a big chromite producer in the future.

TABLE 2.—*Quantity and value of Chromite produced in India during 1914 and 1915.*

—	1914.		1915.	
	Quantity.	Value.	Quantity	Value.
	Tons.	£	Tons.	£
Baluchistan	3,006	1,052	2,161	2,161
Bihar and Orissa	552	301	565	282
Mysore	2,330	1,258	1,041	1,088
Total	5,888	*2,611*	3,767	*3,531*

Coal.

The anomaly of a considerable increase in output accompanied by a decrease in the value of the output has already been referred to. It will be seen from table 4 that the output of 1915 showed an increase amounting to between six and seven hundred thousand tons over that of 1914; the considerable increase in the output combined with the lack of sea-borne transport resulted in a considerable fall in the pit's mouth value in the chief producing areas, the price falling in the Bengal fields from Rs. 3-13-10 per ton in 1914 to Rs. 3-6-2 in 1915, and in Bihar and Orissa from Rs. 3-3-4 to Rs. 2-15-6.

TABLE 3.—*Average price (per ton) of Coal extracted from the Mines in each province during the year 1914.*

Province.	Average price per ton.		
	Rs.	A.	P.
Assam	6	15	6
Baluchistan	9	11	9
Bengal	3	6	2
Bihar and Orissa	2	15	6
Burma	6	0	0
Central India	3	0	0
Central Provinces	4	4	6
Hyderabad	6	0	0
North-West Frontier Province	5	0	0
Punjab	5	6	11
Rajputana	3	15	2

TABLE 4.—*Origin of Indian Coal raised during 1914 and 1915.*

—	Average of last five years.	1914.	1915.
	Tons.	Tons.	Tons.
Gondwana Coalfields	14,023,329	16,039,261	16,673,237
Tertiary Coalfields	404,982	425,002	430,695
Total .	..	16,464,263	17,103,932

As might have been expected the imports of coal were insignificant, amounting only to a little over 175,000 tons. Exports from Bengal to Ceylon rose considerably, while those by sea to Indian ports fell from the normal figure of over 2,000,000 tons to a little over 1,000,000.

TABLE 5.—*Exports of Indian Coal.*

—	1914.		1915.	
	Quantity	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
Ceylon	340,289	203,810	554,885	343,202
Straits Settlements (including Labuan).	111,024	61,230	99,363	55,475
Sumatra	83,698	47,838	64,263	38,688
Other Countries	42,933	26,737	33,290	21,505
Total .	577,944	*339,615*	751,801	*458,870*
Coke	1,802	1,509	1,241	1,327
Total of coal and coke .	579,746	*341,124*	753,042	*460,197*

TABLE 6.—*Imports of Coal, Coke and Patent Fuel during 1914 and 1915.*

—	1914.		1915.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
Australia (including New Zealand)	33,419	36,543	28,106	35,958
Japan	32,232	33,427	18,069	20,533
Natal	39,140	47,066	15,292	16,437
Portuguese East Africa . .	58,742	69,650	52,312	61,519
Transvaal	40,355	53,560	26,448	29,224
United Kingdom . . .	156,863	220,160	30,149	45,948
Other Countries . .	39,612	49,865	3,075	3,303
Total .	**400,363**	*519,271*	**173,451**	*212,922*
Coke	12,729	28,215	10,241	29,221
Patent Fuel	5,666	6,116	6,962	11,007
Government Stores . .	54,738	83,904	12,379	30,635
Total .	**473,496**	*637,506*	**203,033**	*283,785*

The relative proportions of the output contributed by the Jharia and the Raniganj fields respectively were slightly different to that of recent years, the output of the Jharia field having fallen slightly in 1915, whereas that of Raniganj rose by over ½ million tons; the respective percentages of the total output of India as regards these two coalfields were Jharia, 53·44, and Raniganj, 32·07 in 1915 as against 55·55 and 30·04 per cent. in the preceding year.

TABLE 7.—*Provincial Production of Coal during the years 1914 and 1915.*

Province.	1914.	1915.	Increase.	Decrease.
	Tons.	Tons.	Tons.	Tons.
Assam	305,160	311,296	6,136	..
Baluchistan	48,234	43,607	..	4,627
Bengal	4,424,557	4,975,460	550,903	..
Bihar and Orissa . . .	10,661,062	10,718,155	57,093	..
Burma	..	25	25	..
Central India	152,906	139,680	..	13,226
Central Provinces . . .	244,745	253,118	8,373	..
Hyderabad	555,991	586,824	30,833	..
North-West Frontier Province	94	60	..	34
Punjab	54,303	57,911	3,608	..
Rajputana (Bikaner) . .	17,211	17,796	585	..
Total .	**16,464,263**	**17,103,932**	*657,556*	*17,887*

TABLE 8.—*Output of the Gondwana Coalfields for the year 1914 and 1915.*

Coalfields.	1914.		1915.	
	Tons.	Per cent. of Indian Total.	Tons.	Per cent. of Indian Total.
Bengal, Bihar and Orissa—				
Daltonganj . . .	81,680	·50	85,785	·50
Giridih	825,026	5·01	872,647	5·10
Jainti	..	..	40,730	·24
Jharia	9,146,653	55·55	9,140,800	53·44
Bokaro-Ramgarh . .	16,920	} ·15	} 10,232	} ·06
Rajmahal . . .	8,145			
Raniganj . . .	4,946,295	30·04	5,484,596	32·07
Sambalpur (Hingir-Rampur).	60,883	·37	58,825	·34
Darjeeling District (non-act).	17	..	..	..
Central India—				
Umaria . . .	152,906	·93	139,680	·82
Central Provinces—				
Ballarpur . . .	89,292	·54	94,880	·56
Pench valley . . .	95,679	·58	103,152	·60
Mohpani . . .	59,774	·37	55,086	·32
Hyderabad—				
Singareni . . .	555,991	3·38	586,824	3·43
Total .	**16,039,261**	**97·42**	**16,673,237**	**97·48**

TABLE 9.—*Output of Tertiary Coalfields for the years 1914 and 1915.*

Coalfields.	1914.		1915.	
	Tons.	Per cent. of Indian Total.	Tons.	Per cent. of Indian Total.
Assam—				
Makum	303,890		308,071	
Naga Hills . . .	778	1·86	2,872	1·82
Khasi and Jaintia Hills .	492		353	
Baluchistan—				
Khost	39,557	·24	35,782	·21
Sor Range, Mach, etc. .	8,677	·05	7,825	·05
Burma—				
Bhamo	..	..	25	..
North-West Frontier Province—	94		60	
Punjab—		·33		·34
Jhelum	45,867		51,613	
Mianwali . . .	1,557		2,029	
Shahpur . . .	6,879		4,269	
Rajputana—				
Bikaner . . .	17,211	·10	17,796	·10
Total .	425,002	2·58	430,695	2·52

There was a steady rise in the total number of persons employed in the industry, this now amounting to 160,086; the output per person employed, however, was again less than in the preceding year, having fallen from 108·76 tons in 1914 to 106·84 tons in the year under review. There were altogether 178 fatal accidents, the death-rate being 1·11 per thousand persons employed.

Table 10.—*Average number of persons employed daily in the Indian Coalfields during 1914 and 1915.*

Province.	Number of persons employed daily.		Output per person employed.	Number of deaths by accidents.	Death rate per 1,000 persons employed.
	1914.	1915.	1915.	1915.	1915.
Assam	2,888	2,909	107·01	25	8·59
Baluchistan	1,001	963	45·28	3	3·15
Bengal	38,882	42,093	118·20	46	1·09
Bihar and Orissa	90,855	95,292	112·48	83	·87
Burma	..	16	1·56	..	..
Central India	3,038	2,884	48·43	1	·35
Central Provinces	3,254	3,184	79·50	3	·94
Hyderabad	10,141	11,302	51·92	11	·97
North-West Frontier Province.	7	9	6·67	..	..
Punjab	1,161	1,273	45·49	6	4·71
Rajputana (Bikaner)	149	161	110·53	..	..
Total	**151,376**	**160,086**	..	**178**	..
Average	..	..	*106·84*	..	*1·11*

Diamonds.

The decline in the output of diamonds still continued in 1915, and fell from 54·65 carats to 35·99 carats, valued at £603.

Table 11.—*Quantity and Value of Diamonds produced in India during 1914 and 1915.*

—	1914.		1915.	
	Quantity.	Value.	Quantity.	Value.
	Carats.	£	Carats.	£
Central India	54·65	791	35·99	603
Total	**54·65**	*791*	**35·99**	*603*

Gold.

There was a still further increase in the output of gold during the year under review ; the output of the Kolar fields increased by over 8,000 ozs. and that of Anantapur by about 4,000. There was, however, a decline of between 3,000 and 4,000 ozs. in Hyderabad.

TABLE 12.—*Quantity and Value of Gold produced in India during 1914 and 1915.*

—	1914.		1915.		Labour.
	Quantity.	Value.	Quantity.	Value.	
	Ozs.	£	Ozs.	£	
Bihar and Orissa—					
Singhbhum . .	..	..	450	1,800	138
Burma—					
Myitkyina . .	3,635·60	13,905	3,106·83	11,913	213
Katha . . .	12·59	67	16·99	91	
Upper Chindwin .	45·60	268	50·25	295	
Shwebo . .	10·55	55	7·31	36	
Salween . .	..	..	1·20	5	
Hyderabad . . .	21,200	80,479	17,869·7	68,338	1,522
Madras . . .	19,873	82,959	23,870	101,324	2,025
Mysore . . .	562,355	2,159,604	571,199	2,185,409	27,008
Punjab . . .	249·98	994	149·59	604	325
United Provinces . .	5·75	24	7·37	31	26
Total .	**607,388·07**	*2,338,355*	**616,728·24**	*2,369,846*	**31,257**

Graphite.

It is pleasing to be able to replace graphite among the minerals produced in India. Since the closing down of the Travancore mines, attention has been paid to the graphite of Bihar and Orissa and of Rajputana. As a rule, however, the material won is impure and requires special treatment; at present the industry is only in its infancy. The total output of the year was 54 tons in Merwara (Rajputana) valued at £147 and 16 tons in Kalahandi (Bihar and Orissa) valued at £11.

Iron.

There was a considerable decline in the output of iron-ore which fell from a little under 442,000 tons in 1914 to about 390,000 in the

year under review. The amount of pig-iron produced during the year by the Tata Iron and Steel Company, Limited, was 154,509 tons and by the Bengal Iron and Steel Company, Limited, 87,285 tons. The former company produced also 76,355 tons of steel including 16,817 tons of steel rails, whilst the latter company produced 25,634 tons of cast iron castings.

In October, 1915, one of the Tata Iron and Steel Co.'s blast furnaces was put on ferro-manganese and 2,658 tons of that alloy were produced by the end of the year. The average composition of the ferro-manganese was 65 to 75 per cent. manganese, ·6 to ·8 per cent. phosphorus and ·6 to 2 per cent. silicon[1].

TABLE 13.—*Quantity and Value of Iron-ore produced in India during 1914 and 1915.*

—	1914.		1915.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
Bengal—				
Burdwan	1,204	171	2,243	370
Bihar and Orissa—				
Singhbhum	151,662·3	15,083	127,040	10,253
Orissa	249,958	16,674	240,321·8	16,032
Other districts	617	278	386	103
Bombay	·75	..	..	..
Burma	19,482	5,195	15,526	4,140
Central India	326·5	59	..	..
Central Provinces	18,402	3,198	4,747	986
United Provinces	21·7	7	6·7	2
Total	**441,674·25**	*40,665*	**390,270·5**	*31,886*

Jadeite.

There is nothing further to record about the jadeite industry; the decline noticed in previous years still continues while the figures returned for exports also continue to be greater than those for production. The former figures therefore are adopted as more likely to indicate the true condition of the industry.

[1] Information furnished by the Company.

TABLE 14.—*Quantity and Value of Jadeite produced in Burma during 1914 and 1915.*

—	1914.		1915.	
	Quantity.	Value.	Quantity.	Value.
Myitkyina	Cwt. 3,764·75	£ 13,643	Cwt. 3,692·75	£ 12,678

TABLE 15—*Export of Jadeite by Sea during 1914 and 1915.*

—	1914.		1915.	
	Quantity.	Value.	Quantity.	Value.
Burma	Cwt. 2,959	£ 40,092	Cwt. 5,001	£ 52,070

Lead.

The output of the Bawdwin mines maintained the steady increase recorded last year, the ore and slag smelted being over 42,000 tons and representing an increase of nearly 9,000 tons over the output of the preceding year. Owing to the rise in the price of lead the value of the output was considerably higher than it would have been in normal times. I am indebted to the Resident Manager, Burma Mines, Limited, for a considerable amount of information as to the present development of the mines. The total production of the metal during 1915 amounted to 13,522 tons of hard lead, of which 6,947 tons were refined and sold in the Eastern markets and 6,575 tons, containing 284,875 ozs. of silver, were shipped to England to be refined.[1] Extensive concentration tests have been carried out on the ore. The roasting plant, which consists of three roasters in operation and two under construction will, when completed, have a daily capacity of 150 to 200 tons of ore. It has not yet been found practicable to produce fine silver on the spot, but retort furnaces and a cupelling furnace have been built with a view to

[1] The output for the first few months of the year 1916 indicates that the year's production will be considerably higher than that of last year and the Resident Manager states that the daily production "at present" (June, 1916) is at the rate of over 50 tons of lead containing from three to four thousand ounces of silver.

future refining. Practically no zinc concentrates were exported during the year (*infra*, page 168).

The amount of lead-ore produced otherwise than at Bawdwin during the past year was insignificant, being 28 tons from the Southern Shan States and 7 tons from the Drug district of the Central Provinces.

TABLE 16.—*Production of Silver-lead ore during 1914 and 1915.*

—	1914.			1915.		
	Quantity.	Value.		Quantity.	Value.	
	Lead-ore and slag.	Lead-ore and lead.	Silver.	Lead-ore and slag.	Lead-ore and lead.	Silver.
	Tons.	£	£	Tons.	£	£
Burma—						
Northern Shan States.	8,769 (ore)	27,346(*a*)	13,039	4,094 (ore)	36,301(*d*)	8,540
	24,901 (slag)	174,933(*b*)	13,857	32,534 (slag)	273,067(*e*)	20,258
				5,620 (gossan flux)	6,709 (*f*)	2,301
Southern Shan States.	12	32	..	28	75	..
Central Provinces—						
Drug . .	3·25	19	..	7	30	..
Total .	33,685·25	*202,330*	*26,896*(*c*)	42,283	*316,182*	*31,099*(*g*)

(*a*) Value of 1,426 tons of lead extracted.
(*b*) Value of 9,122 tons of lead extracted.
(*c*) Value of 236,446 ozs. of silver extracted.
(*d*) Value of 1,553 tons of lead extracted.
(*e*) Value of 11,682 tons of lead extracted.
(*f*) Value of 287 tons of lead extracted.
(*g*) Value of 284,875 ozs. of silver extracted.

Magnesite.

There was a considerable increase in the production of magnesite in the Salem district, the outturn being 7,450 tons valued at £3,973 as against 399 tons in the preceding year. During 1915, however, none was produced in Mysore.

Manganese.

Manganese was one of the minerals which were largely affected by the war, the exports being restricted almost entirely to consignments to the United Kingdom, with a comparatively small quantity to the United States; the quantity exported fell from about 538,000 tons in 1914 to less than 420,000 tons in the year under review. The latter figure again is only a little more than half the quantity exported in the year 1913. This naturally resulted in a considerable decrease in the production of ore which fell from a little under 683,000 tons in 1914 to a little over 450,000 tons, a decrease of 34 per cent. It is impossible to estimate accurately the value of this outturn since the price of the ore at the present time is purely artificial and depends to a great extent on the cost of freight; at the prices which have prevailed during the year, the value, based on the usual methods of calculation, would amount to £929,546, which, however, is not the true value of the material extracted, but is deduced from the value of only so much of the outturn as was actually exported during the year. If the conditions which prevailed during the year 1915 were to continue for a considerable period, the above figures would no doubt fairly represent the true value of the output, but if the stringency in the matter of markets and of freights were to be relieved, the value of the material produced, but not yet exported, would naturally be considerably reduced. There are no means therefore of estimating more accurately the value of the year's output; but it is considered desirable to draw attention to the anomaly of a heavy fall in the quantity produced accompanied by an apparent rise in the value of the total production, an anomaly which is due to the artificial state of the manganese market.

TABLE 17.—*Quantity and Value of Manganese-ore produced in India during 1914 and 1915.*

	1914.		1915.	
	Quantity.	Value f. o. b. at Indian ports.	Quantity.	Value f. o. b. at Indian ports.
	Tons.	£	Tons.	£
Bihar and Orissa—				
Singhbhum . . .	..	..	507	993
Gangpur . . .	6,070	7,613	..	..
Bombay—				
Chota Udepur . .	7,735	9,701	..	..
Panch Mahals . .	19,488	24,441	26,915	52,709
Central India—				
Jhabua	6,642	6,144	366	558
Central Provinces—				
Balaghat . . .	221,159	296,722	180,609	374,189
Bhandara	82,055	110,090	78,627	166,427
Chhindwara . . .	87,114	116,878	46,941	99,358
Nagpur . . .	174,562	234,204	93,027	196,907
Jabalpur . . .	..	..	11	23
Madras—				
Sandur	33,643	29,858	..	..
Vizagapatam . . .	26,375	23,408	288	418
Mysore	18,055	18,205	23,125	37,964
Total .	682,898	*877,264*	450,416	*929,546*

Mica.

Like that of manganese, the mica industry was also affected by the war, exports to countries other than the United Kingdom being very largely restricted. This resulted in a decrease of over 30 per cent. in production ; there was also a corresponding decrease in the amount exported which fell from over 2,000 tons in 1914 to a little over 1,500 tons in the year under review.

TABLE 18.—*Quantity and Value of Mica produced in India during 1914 and 1915.*

—	1914.		1915.	
	Quantity.	Value.	Quantity.	Value.
	Cwt.	£	Cwt.	£
Bihar and Orissa	33,275	46,796	22,195	49,980
Madras	5,989·5	36,140	3,894	20,728
Rajputana	1,192·1	4,968	1,042	3,398
Mysore	50	186	8·7	33
Total	40,506·6	*88,090*	27,139·7	*74,139*

Monazite.

There was a small decrease, from 1,185·65 tons valued at £41,411 in 1914 to 1,107·9 tons valued at £33,283 in the year under review in the output of monazite from Travancore and the industry was considerably disorganised by the war. Enemy interests in the company working the monazite sands were found to be considerable; but these have now been eliminated, and the industry has been placed on a satisfactory basis.

Petroleum.

The output of petroleum increased by nearly 30 million gallons, from a little under 260 million gallons in the year 1914 to a little over 287 million in the year under review; the value of the production during 1915 was over $1\frac{1}{4}$ million pounds sterling. The chief increase was in the Yenangyaung field, where the output rose by about 24 million gallons. Wells continue to be carried down into the deep sands, which are still found to be productive at depths of nearly three thousand feet, and there is no indication yet as to the limiting depth at which oil will be found in this field.

There was also an increase, amounting to over $3\frac{1}{2}$ million gallons, in the output of the Singu field and an increase of over $\frac{1}{2}$ million gallons in Minbu. The recent discovery of an oil-sand at a considerable depth on the southern extension of the Minbu belt has led to a considerable revival of interest in the adjoining areas.

For the first time the returns from the Punjab include an appreciable amount of petroleum; this is from the newly discovered field at Khaur, where borings are being put down by the Attock Oil Company; the output during 1915 is returned at ¼ million gallons.

TABLE 19.—*Quantity and Value of Petroleum produced in India during 1914 and 1915.*

—	1914.		1915.	
	Quantity.	Value.	Quantity.	Value.
	Gallons.	£	Gallons.	£
Burma—				
Akyab	12,948	249	12,045	231
Kyaukpyu . . .	25,987	777	23,220	716
Magwe (Yenangyaung) .	174,981,799	673,525	198,809,315	765,240
Myingyan (Singu) . .	73,409,518	244,698	77,005,880	448,307
Pakokku (Yenangyat) .	4,516,685	16,729	4,099,345	15,525
Minbu	1,683,190	7,013	2,316,207	9,651
Thayetmyo . . .	22,836	95	25,920	108
Assam—				
Digboi (Lakhimpur) .	4,688,547	15,466	4,550,150	15,009
Punjab—				
Attock	..	..	250,000	2,000
Mianwali . . .	1,200	13	1,494	16
Total . .	259,342,710	*958,565*	287,093,576	*1,256,803*

Imports of kerosene during the year under review were considerably less than in the preceding year, the total quantity imported falling from nearly 84 million gallons to a little over 68 million gallons. The greater part of the decrease was in the imports from Borneo, but imports from Persia fell by nearly 2 million gallons, and from the United States by about 3½ million gallons. There was a small rise in the quantity of paraffin wax exported.

TABLE 20.—*Imports of Kerosene Oil during 1914 and 1915.*

—	1914.		1915.	
	Quantity.	Value.	Quantity.	Value.
	Gallons.	£	Gallons.	£
From—				
Borneo	26,966,642	661,243	17,861,500	451,258
Persia	2,765,685	81,237	783,669	23,490
Russia	1,661,870	43,662	..	..
Straits Settlements (including Labuan)	5,553,268	147,183	6,156,330	161,489
United States of America	46,931,641	1,328,352	43,371,165	1,326,929
Other countries	428	15	426	47
Total	**83,879,534**	*2,261,692*	**68,173,090**	*1,963,213*

TABLE 21.—*Export of Paraffin Wax from India during 1914 and 1915.*

—	1914.		1915.	
	Quantity.	Value.	Quantity.	Value.
	Cwt.	£	Cwt.	£
To—				
United Kingdom	95,210	144,171	153,267	221,974
China	69,775	94,255	46,551	57,551
Japan	58,355	88,506	57,500	87,209
Other countries	139,336	207,808	126,983	192,263
Total	**362,676**	*534,740*	**384,301**	*558,997*

Platinum.

Every year a small amount of platinum figures in the returns of the precious metals won by the Burma Gold Dredging Company at Myitkyina ; it never amounts to more than a few ounces, the figures for 1915 being 17·7 ounces valued at £100.

Ruby, Sapphire and Spinel.

There was a decrease of about 50,000 carats in the output of the Burma Ruby Mines, which fell from a little under 305,000 carats valued at £43,000 to a little over 251,000 carats valued at £36,300.

TABLE 22.—*Quantity and Value of Ruby, Sapphire and Spinel produced in India during 1914 and 1915.*

—	1914.		1915.	
	Quantity.	Value.	Quantity.	Value.
Burma—				
Mogok	193,333 (Rubies)	40,781	167,904 (Rubies)	34,881
Do.	56,709 (Sapphires)	2,052	39,718 (Sapphires)	1,276
Do.	54,830 (Spinels)	300	43,827 (Spinels)	141
Total .	**304,872**	*43,133*	**251,449**	*36,298*

Salt.

There was an increase of nearly 30 per cent. in the amount of salt produced in India during the year 1915 as compared with the preceding year, the total production, including that of rock-salt, amounted to a little less than 1¾ million tons valued at £660,000. The imports fell from a little over 562,000 tons to nearly 520,000 tons, but there was a considerable rise in the value of the import owing to the artificial conditions introduced by the war.

TABLE 23.—*Quantity and Value of Salt produced in India during 1914 and 1915.*

—	1914.		1915.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
Aden	144,463	57,636	352,232	47,838
Bengal.	6	2	(*a*)	..
Bombay and Sind . .	486,898	113,453	524,257	129,180
Burma.	21,522	75,536	28,521	108,870
Gwalior State . . .	99	271	127	347
Kashmir	73	55	36·7	27
Madras	298,862	115,494	345,714	209,897
Northern India . . .	396,302	120,842	494,634	164,095
Total .	**1,348,225**	*483,289*	**1,745,521·7**	*660,254*

(*a*) Quantity of salt educed was 24½ maunds (nearly 1 ton) valued at Rs. 9-3-0.

TABLE 24.—*Quantity and Value of Rock Salt produced in India during 1914 and 1915.*

—	1914.		1915.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
Salt Range	135,519	19,113	154,772	26,332
Kohat	18,239	1,810	21,387	2,123
Mandi	2,792	3,325	3,633	4,327
Total .	**156,550**	*24,248*	**179,792**	*32,782*

TABLE 25.—*Quantity and Value of Salt imported into India during 1914 and 1915.*

—	1914.		1915.	
	Quantity.	Value.	Quantity.	Value.
	Tons	£	Tons	£
Aden and Dependencies .	153,928	146,790	102,286	108,995
Egypt	93,615	101,693	125,123	224,218
Germany	35,014	40,174	(a)1,020	926
Spain	68,119	64,410	102,286	152,736
Turkey, Asiatic . . .	62,255	60,896	..	2
United Kingdom . . .	103,017	104,395	131,018	138,478
Other countries . . .	46,500	42,209	57,790	52,617
Total .	**562,448**	*560,657*	**519,523**	*677,972*

(*a*) From prize cargoes.

Saltpetre.

The demand for saltpetre for the manufacture of explosives has given a considerable impetus to the indigenous industry; the effect of this is seen in the increased exports during the year 1915 which were 46 per cent. higher than those of the preceding year; about 70 per cent. of the quantity exported went to the United Kingdom.

TABLE 26.—*Quantity and Value of Saltpetre produced in India during 1914 and 1915.*

—	1914.		1915.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
Bihar	4,896	76,946	5,673	113,147
Bombay (Cutch) . . .	1	11	..	..
North-West Frontier Province	2·2	51	..	..
Punjab	3,520	73,404	5,253	109,548
Rajputana	405·9	4,232	137	2,568
United Provinces	6,664	117,818	7,035	148,628
Total .	**15,489·1**	*272,462*	**18,098**	*373,891*

TABLE 27.—*Distribution of Saltpetre exported during 1914 and 1915.*

—	1914.		1915.	
	Quantity.	Value.	Quantity.	Value.
	Cwt.	£	Cwt.	£
Ceylon	44,085	28,674	57,221	45,393
China	49,266	40,305	31,692	27,335
Mauritius and Dependencies .	23,406	17,778	15,146	13,408
United Kingdom	127,936	112,924	296,106	315,372
United States of America .	19,163	15,096	..	..
Other countries	21,300	19,987	18,443	20,876
Total .	**285,156**	*234,764*	**418,608**	*422,384*

Silver.

Although no silver ores are worked in India a certain amount of that metal is obtained as a by-product in the extraction of lead at Bawdwin, and of gold at Anantapur, where the Jibutil Gold Mines of Anantapur, Limited, won 512 ozs. during the year under review. As already stated above (page 157) the Burma Mines, Limited, exported during the year argentiferous lead bullion containing 284,875 ozs. of silver.

Tin.

There was a considerable increase in the amounts of block-tin and tin-ore extracted in Burma; the value of the output rose from £38,203 in 1914 to £54,980 in the year under review. The imports into India of unwrought tin fell by about 30 per cent. in 1915 as compared with the preceding year.

TABLE 28.—*Quantity and Value of Tin and Tin-ore for the years 1914 and 1915.*

—	1914.				1915.			
	BLOCK TIN.		TIN-ORE.		BLOCK TIN.		TIN-ORE.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Cwt.	£	Cwt.	£	Cwt.	£	Cwt.	£
Bihar and Orissa Hazaribagh	1	16	..	..	·7	6	..	..
Burma—								
Mergui .	1,963	16,235	1,861	9,263	2,553·5	20,534	1,762·25	8,678
Southern Shan States.	..	..	2,767	8,993	..	..	6,613·9	24,802
Tavoy .	..	..	767	3,696	6	4	253	956
Total .	**1,964**	*16,251*	**5,395**	*21,952*	**2,554·8**	*20,544*	**8,629·15**	*34,436*

TABLE 29.—*Imports of Tin unwrought (blocks, ingots, bars and slabs) into India during 1914 and 1915.*

—	1914.		1915.	
	Quantity.	Value.	Quantity.	Value.
	Cwt.	£	Cwt.	£
From—				
United Kingdom . .	5,113	40,806	2,722	23,670
Straits Settlements (including Labuan).	35,340	312,318	27,014	224,524
Other Countries . .	254	1,969	466	3,883
Total .	**40,707**	*355,093*	**30,202**	*252,077*

Tungsten.

The demand for wolfram for the manufacture of high-speed steel gave an impetus to the wolfram industry of Tavoy towards the latter part of the year under review; and,—as already pointed out in the General Report of the Geological Survey of India for the year 1915, published in this volume of the *Records* (*supra*, page 24),—steps were taken by Government to increase the efficiency of the local mining methods; as those steps did not become effective until the latter part of the year, the result will be apparent in the returns for the following year rather than in those for the year under review. The output, however, for the year 1915 showed an increase of about 13 per cent. over that of the preceding year, while the value of the output rose from £178,543 to £296,772. The industry is gradually being placed on a sound and firm basis, and it is hoped that before long the annual outturn will be twice as great as it was before the war.

TABLE 30.—*Quantity and Value of Tungsten-ore produced in Burma during 1914 and 1915.*

—	1914.		1915.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
Burma—				
Mergui	194	16,647	232·3	29,554
Southern Shan States	138·4	8,993	330·7	24,802
Tavoy	1,976·6	152,333	2,032·9	235,827
Thaton	17	570	49·4	6'589
Total	**2,326**	*178,543*	**2,645·3**	*296,772*

Zinc.

In the years 1913 and 1914 considerable amounts of zinc concentrates were shipped to Belgium and Germany for reduction; in 1915 only 196 tons were exported as against over 8,000 tons in the preceding year. The question of the ultimate treatment of the Bawdwin concentrates is an important one for India, since, should it be found feasible to erect zinc smelteries in this country, the resultant production of large quantities of cheap sulphuric acid should have a far-reaching effect on industrial development.

III.—MINERALS OF GROUP II.

Agate. There was a considerable rise in the amount of agate produced during the year in Cambay, the quantity having increased from 101 tons valued at £175 in the year 1914 to 508 tons valued at £1,019.

Alum. There was a fall in the amount of alum produced, the figures being 7,026 cwt. valued at £4,393 in 1915, as against 8,731 cwt. valued at £4,649 in the preceding year.

Amber. The production of amber also fell slightly from 13 cwt. to 11½ cwt., the value of the latter being £199.

Antimony. A small quantity, amounting to 13 tons, of stibnite was produced in the Amherst district of Burma; the deposit, however, is said to be small and of no particular value.

Bauxite. The amount of bauxite produced in 1915 was 876 tons valued at £29. This was extracted chiefly by the Katni Cement and Industrial Company Limited at Katni. Experiments are in progress with a view to the manufacture of bauxite bricks from this material.

Aquamarine. A discovery of aquamarine in Kashmir resulted in the collection of 3¾ cwt. of stones of good quality and considerable value, some being large, of excellent quality and of great beauty.

Building-stones. The returns for building-stones and road-metal show a value of £204,652 for the year 1915 as against £218,879 in the preceding year. As has been pointed out in previous reviews, however, these figures are only partial.

Clay. The figures for clay are also very incomplete and show only an output of 64,139 tons valued at £3,834.

Copper. There was a considerable increase in the amount of copper-ore produced during the year 1915 over the output of the preceding year; the total production was nearly 9,000 tons valued at over £14,000.

TABLE 31.—*Quantity and Value of Copper-ore produced in India during 1914 and 1915.*

—	1914.		1915.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
Bihar and Orissa—				
Singhbhum . . .	4,400	6,600	8,010	12,015
Northern Shan States .	924	693(*b*)	875	2,366
United Provinces (Jhansi)	(*a*)	1	..	..
Total .	**5,324**	*7,294*	**8,885**	*14,381*

(*a*) Quantity produced was only 1·5 qr.
(*b*) Diminished value was due to increased cost of sea freight and smelting charges in England.

Corundum.

There was a considerable fall in the amount of corundum produced during the year 1915, the figures being 1,246 cwt. valued at £277 against 2,360 cwt. in the year 1914 valued at £447; most of the output came from Mysore.

Garnet.

The garnet industry was almost entirely suspended owing to the lack of demand for garnets, and the workings in the Kishengarh State, which during the year 1914 produced 464 cwt. of garnet valued at £4,333, were closed during the year under review. Similarly the workings in the Tinnevelly district of the Madras Presidency, which produced over 1,000 tons of garnet sand for abrasive purposes in the year 1914, produced nothing during the year under review. The total output for the year 1915 amounted only to 115 cwt. most of which was won in the Nizam's Dominions.

Gypsum.

The amount of gypsum produced was almost exactly the same as in the preceding year, namely 22,563 tons valued at £979.

Ochre.

There was a slight decrease in the amount of ochre produced, from 608 tons valued at £157 in 1914 to 476 tons valued at £459 in the year under review. Practically the whole output came from Central India.

TABLE 32.—*Production of Building Materials and Road Metal in India during the year 1915.*

	GRANITE.		LATERITE.		LIME.		LIMESTONE AND KANKAR.		MARBLE.		SANDSTONE.		SLATE.		TRAP.		MISCELLANEOUS.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£	Tons.	£	Tons.	£	Tons	£	Tons.	£	Tons.	£	Tons.	£	Tons.	£
Assam .	..	..	..	..	..	..	103,736	6,395	..	..	..	..	..	..	..	..	..	..
Bihar and Orissa.	14,085	3,260	2,732	36	..	..	242,864	35,245	..	..	21,092	1,317	2,800	3,067	7,469	876	376,571	10,781
Bombay .	..	..	..	..	..	..	9,080	333	..	..	..	..	..	..	..	..	..	..
Burma .	122,173	10,675	228,124	20,554	..	..	160,498	7,933	..	..	51,539	4,022	..	..	..	..	324,809	24,009
Central India	..	..	..	..	18,973	1,296	33,715	1,801	..	..	..	..	..	..	..	..	..	..
Central Provinces.	..	..	16,445	876	..	..	63,079	5,201	..	..	..	..	..	..	..	..	186	2
Hyderabad	..	..	..	..	..	..	..	..	..	..	..	..	not known	1,341	..	..	..	..
Madras .	94,618	2,784	94,574	3,405	..	..	11,250	572	..	..	..	..	..	..	..	..	85,460	4,071
North-West Frontier Province.	..	..	..	..	..	..	6,444	290	..	..	..	..	..	..	..	..	..	..
Punjab .	..	..	..	..	..	..	28,938	1,514	..	..	38,215	3,051	7,910	7,328	..	..	4,744	74
Rajputana .	..	..	..	..	..	..	3,008	549	3,735	3,047	39,781	13,315	..	..	..	..	39,806	3,015
United Provinces.	..	..	..	..	18	11	408	56	..	..	166,185	18,471	1,045	385	..	..	2,934	513
Total .	230,876	*16,719*	341,875	*24,871*	18,991	*1,307*	662,570	*59,859*	3,735	*3,047*	316,812	*40,176*	11,755	*12,121*	7,469	*876*	888,803	*46,186*

Steatite.

There was a slight rise in the quantity, and fall in the value, of steatite produced during the year under review. The figures are given in table 33.

TABLE 33.—*Quantity and Value of Steatite produced in India during 1914 and 1915.*

—	1914.		1915.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
Bihar and Orissa—				
Singhbhum . . .	(*a*)	400	(*a*)	333
Mayurbhanj . . .	60	173	50	133
Central Provinces—				
Jubbulpore . . .	502	429	329	336
Madras—				
Bellary	25	17	28	19
Kurnool . . .	210	1,576	..	..
Nellore	60	715	45·75	407
Salem	..	..	529·4	720
United Provinces—				
Hamirpur . . .	120	744	95	630
Jhansi	22	92	..	..
Total .	999	*4,146*	1,077·15	*2,578*

(*a*) Quantity not returned.

IV.—MINERAL CONCESSIONS GRANTED.

TABLE 34.—*Statement of Mineral Concessions granted during 1915.*

ASSAM.

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Khasi and Jaintia Hills.	(1) Mr. R. D. Coggan .	Gold and certain other allied minerals.	P. L. (renewal).	12,704	14th April, 1915.	1 year.
Do. .	(2) Do. .	Tin and wolfram .	P. L. (renewal).	12,704	Do. .	Do.
Do. .	(3) Do. .	Gold, tin and certain other allied minerals.	P. L. (renewal).	8,160	Do. .	Do.

BALUCHISTAN.

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Kalat .	(4) Sirdar Bahawal Khan, Satikzai of Bolan.	Coal . . .	M. L. .	80	1st July, 1915.	30 years.
Quetta .	(5) Mian Mohammad Ismail of Quetta.	Do. . .	M. L. .	169·70	Do. .	Do.
Sibi . .	(6) W. C. Clements, Esq., of Shahrig.	Do. . .	M. L. .	80	1st January, 1915.	Do.
Do. . .	(7) Khan Bahadur B. D. Patel, C.I.E.	Do. . .	M. L. .	80	Do. .	Do.
Zhob . .	(8) The Baluchistan Mining Syndicate.	Chromite . .	M. L. .	80	Do.	Do.
Do. . .	(9) Do. .	Do. . .	M. L. .	80	Do. .	Do.
Do. . .	(10) Baluchistan Chrome Company.	Do. . .	M. L. .	80	1st July, 1915.	Do.

BENGAL.

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Chittagong	(11) Messrs. Burma Oil Co., Ltd.	Mineral oil . .	P. L. .	4,000	1st September, 1914.	2 years.

BIHAR AND ORISSA.

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Hazaribagh	(12) Babu Lakshmi Narain Sukhani.	Mica . . .	P. L. .	80	15th July, 1915.	1 year.
Palamau .	(13) Bengal Coal Co., Ld.	Coal . . .	P. L. .	6,119	9th July, 1915.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BIHAR AND ORISSA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Sambalpur .	(14) Hingir Rampur Coal Mining Co., Bombay.	Coal . .	M. L. .	720·2	1st January, 1915.	30 years.
Do. .	(15) Karim Hussain of Rajkote.	Mica . . .	P. L. .	882·78	22nd December, 1915.	1 year.
Singhbhum	(16) The Bengal Iron and Steel Co., Ld.	Iron-ore . .	M. L. .	2,035·20	The lease has not yet been executed.	30 years.
Do. .	(17) Mr. A. C Moitra .	Gold . . .	P. L. .	6·5	4th June, 1915.	1 year.
Do. .	(18) Do. . .	Gold, manganese and bauxite.	P. L. .	320	Do.	Do.
Do. .	(19) Rai Srinath Pal Bahadur.	Manganese . .	P. L. (renewal).	about 400	9th August, 1914.	Do.
Do. .	(20) Mr. L. P. E. Pugh .	Chromite . .	P. L. (renewal).	3,136	5th June, 1915.	Do.
Do. .	(21) The Bengal Iron and Steel Co., Ltd.	Iron-ore . .	P. L. .	1,267·2	21st December, 1915.	Do.
Do. .	(22) Babu N. N. Goswami of Calcutta.	Manganese . .	P. L. .	67·54	6th December, 1915.	Do.
Do. .	(23) Do. . .	Do. . .	P. L. .	3·86	Do. .	Do.
Do. .	(24) Do. . .	Do. . .	P. L. .	25	Do. .	Do.
Do. .	(25) Mr. S. Luxman Rao Naidu of Nagpur.	Chromite . .	P. L. (renewal).	927·38	16th October, 1915.	9 months.
Do. .	(26) Do. . .	Do. . .	P. L. (renewal).	1,621·18	Do. .	Do.

BURMA.

Akyab .	(27) The Burma Oil Co., Ltd.	Mineral oil . .	P. L. .	3,620	15th September, 1915.	1 year.
Amherst .	(28) Maung Pe . .	All minerals (except oil).	P. L. .	537·6	9th January, 1915.	Do.
Do. .	(29) The Mudon Mineral Syndicate.	Do. .	P. L. (renewal).	640	11th August, 1914.	Do.
Do. .	(30) Mr. H. E. Singleton	Do. .	P. L. .	2,560	3rd May, 1915.	Do.
Do. .	(31) The Mudon Mineral Syndicate.	Do. .	P. L. (renewal).	640	11th August, 1915.	Do.
Do. .	(32) Mr. L. Sisman .	Do. .	P. L. (renewal).	640	10th June, 1915.	Do.
Do. .	(33) Mrs. M. M. Hla Oung.	Do. .	P. L. (renewal).	2,880	28th July, 1915.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Amherst .	(34) Mrs. M. M. Hla Oung.	Tin, wolfram, gold, silver, copper and antimony.	P. L. .	640	14th October, 1915.	1 year.
Do. .	(35) Mr. C. E. Low .	All minerals (except oil).	P. L. .	640	18th December, 1915.	Do.
Bhamo .	(36) Mr. C. H. Hearsey .	Do. .	P. L. .	5,517	7th June, 1915.	Do.
Katha .	(37) Messrs. Jamal Bros. & Co., Ltd.	Tin, wolfram, gold, silver and copper.	P. L. .	4,800	15th May, 1915.	Do.
Do. .	(38) A. M. Hoosein Hamadanee.	Zinc, lead and silver.	P. L. .	960	Do.	Do.
Do. .	(39) Do. . .	Gold, silver, tin, wolfram and copper.	P. L. .	2,796·80	9th July, 1915.	Do.
Do. .	(40) Messrs. Jamal Bros. & Co., Ltd.	Tin, wolfram, silver, copper, lead, zinc and gold.	P. L. .	23,568·64	3rd November, 1915.	Do.
Kyaukse .	(41) Do. . .	All minerals (except oil).	P. L. .	2,733	26th April, 1915.	Do.
Do. .	(42) Do. . .	Do. .	P. L. .	12,160	11th October, 1915.	Do.
Lower Chindwin.	(43) Do. . .	Copper, tin, lead, zinc, silver and gold.	P. L. .	1,260	23rd March, 1915.	Do.
Do.	(44) Mr. A. S. Jamal .	Do. .	P. L. .	1,680	Do. .	Do.
Do. .	(45) Messrs. Jamal Bros. & Co., Ltd.	Copper . .	P. L. (renewal).	1,440	1st August, 1915.	Do.
Magwe .	(46) The Burma Oil Co., Ltd.	Mineral oil . .	P. L. (renewal).	2,240	19th February, 1915.	Do.
Mergui .	(47) Mrs. B. I. Jewett .	All minerals (except oil).	P. L. .	471·04	12th February, 1914.	Do.
Do. .	(48) Mahomed Haniff .	Do. .	P. L. .	2,580·48	6th January, 1915.	Do.
Do. .	(49) Mr. J. J. A. Page .	Do. .	P. L. .	1,760	18th January, 1915.	Do.
Do. .	(50) U. Shwe I . .	Do. .	P. L. .	2,816	23rd March, 1915.	Do.
Do. .	(51) Saw Long Lee	Do. .	P. L. .	204·8	26th January, 1915.	Do.
Do. .	(52) Mrs. B. I. Jewett	Do. .	P. L. (renewal).	3,056·64	12th February, 1914.	Do.
Do. .	(53) Messrs. Moola Dawood Sons & Co.	Do. .	P. L. (renewal).	3,011·04	15th November, 1914.	Do.
Do. .	(54) Lim Aw Kyi . .	Do. .	P. L. (renewal).	207·36	24th July, 1914.	Do.
Do. .	(55) Mr. C. S. Baker .	Do. .	P. L. (renewal).	600	31st December, 1914.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Mergui .	(56) E. Ahmed . .	All minerals (except oil).	P. L. (renewal).	2,749·44	27th January, 1915.	6 months.
Do. .	(57) Do. . .	Do. .	P. L. (renewal).	1,318·56	30th November, 1914.	1 year.
Do. .	(58) U. Shwe Don .	Do. .	P. L. (renewal).	793·60	9th February, 1915.	Do.
Do. .	(59) U. Po Tsee . .	Do. .	P. L. (renewal).	381·44	Do. .	Do.
Do. .	(60) Saw Leng Lee .	Do. .	P. L. (renewal).	664·48	2nd March, 1915.	6 months.
Do. .	(61) Messrs. Wightman & Co.	Do. .	P. L. .	2,421·76	3rd May, 1915.	1 year.
Do. .	(62) Maung Shwe Thi .	Do. .	P. L. (renewal).	852·48	18th February, 1915.	6 months.
Do. .	(63) U. Ne Gyi . .	Do. .	P. L. (renewal).	3,200	6th June, 1915.	Do.
Do. .	(64) E. Ahmed . .	Do. .	P. L. (renewal).	2,316·80	30th April, 1915.	Do.
Do. .	(65) Mr. J. J. Wytema .	Do. .	P. L.	2,829·80	30th September, 1915.	1 year.
Do. .	(66) U. Shwe I . .	Do. .	P. L. (renewal)	473·60	9th February, 1915.	Do.
Do. .	(67) G. Shwe Yin . .	Do. .	P. L. (renewal).	1,002·52	21st July, 1915.	Do.
Do. .	(68) Mr. E. Ahmed .	Do. .	P. L. (renewal).	2,747·44	27th July, 1915.	Do.
Do. .	(69) Messrs. Wightman & Co.	Do. .	P. L. (renewal).	1,550	26th August, 1915.	Do.
Do. .	(70) Sit Khwet . .	Do. .	P. L. (renewal).	1,373·28	24th July, 1915.	Do.
Do. .	(71) Lim Aw Kyi . .	Do. .	P. L. (renewal).	207·36	Do. .	Do.
Do. .	(72) Maung Shwe Thi .	Do. .	P. L. (renewal).	852·48	18th August, 1915.	Do.
Do. .	(73) Saw Leng Lee .	Do. .	P. L. (renewal).	664·48	2nd September, 1915.	Do.
Do. .	(74) Mr. A. H. Noyce .	Do. .	P. L. .	100	26th November, 1915.	Do.
Do. .	(75) Maung Kyaw Din .	Do. .	P. L. .	434·70	18th December, 1915.	Do.
Do. .	(76) Mrs. B. I. Jewett .	Do. .	P. L. (renewal).	3,056·64	12th February, 1915.	Do.
Do. .	(77) Do. . .	Do. .	P. L. (renewal).	471·04	Do. .	Do.
Do. .	(78) Maung Kyaw Din .	Do. .	P. L. (renewal).	3[illegible]8·64	1st August, 1915.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Mergui .	(79) E. Ahmed . .	All minerals (except oil).	P. L. (renewal).	2,316·80	30th October, 1915.	One year or until orders are passed on the application for a mining lease.
Minbu .	(80) Messrs. The British-Burma Petroleum Co., Ltd.	Mineral oil . .	P. L. (renewal).	174	20th November, 1914.	1 year.
Do. .	(81) Do. . .	Do. . .	P. L. (renewal).	440·32 Southern half of 16 N. and northern portion of 17 N.	27th November, 1914.	Do.
Do. .	(82) Do. . .	Do. . .	P. L. .	614	3rd May, 1915.	Do.
Do. .	(83) Messrs. The Indo-Burma Petroleum Co., Ltd.	Do. . .	P. L. .	960 Eastern half of Blocks I.S. and J.S. of the Minbu Oil Field.	28th June, 1915.	Do.
Do. .	(84) Do. . .	Do. . .	P. L. .	320 Northern half of Block 16 N.	6th August, 1915.	Do.
Do. .	(85) Messrs. The Moola Oil Co., Ltd.	Do. . .	M. L. .	640 Block 19 P. in the Minbu Oil Field.	25th August, 1913.	30 years.
Do. .	(86) Do. . .	Do. . .	M. L. .	2,513·40 Blocks B.S., C.S., D.S., and E.S., in the Minbu Oil Field.	10th January, 1914.	Do.
Do. .	(87) Messrs. The British-Burma Petroleum Co., Ltd.	Do. . .	P. L.	640	17th May, 1915.	1 year.
Do. .	(88) Messrs. The Yomah Oil Co., Ltd.	Do. . .	P. L. .	2,570 (Blocks 4 P., 8 P., 12 P., and portions of blocks 11 P. and 16 P. in the Minbu Oil Field.)	5th July, 1915.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Minbu .	(89) Messrs. The Yomah Oil Co., Ltd.	Mineral oil .	P. L. .	673·28 Undemarcated block 15P. and the northern portion of block 16P. in the Minbu Oil Field.	6th October, 1915.	1 year.
Myingyan	(90) Messrs. The British-Burma Petroleum Co., Ltd.	Do. . .	P. L. .	640 Block 52N. in the Singu Oil Field.	24th November, 1915.	Do.
Myitkyina .	(91) Mr. B. A. Baldwin .	Gold and platinum	P. L. (renewal).	1,440	8th October, 1914.	Do.
Do. .	(92) Mr. C. W. Chater .	Gold, platinum and allied metals.	P. L. .	960	1st June, 1915.	Do.
Do. .	(93) Do. .	Do. . .	P. L. .	480	18th June, 1915.	Do.
Do. .	(94) Do. . .	Do. . .	P. L. .	640	Do. .	Do.
Do. .	(95) The Burma Gold Dredging Co., Ltd.	Gold and other minerals (except oil).	P. L. .	1,466	1st September, 1915.	Do.
Do. .	(96) Mr. H. F. Leslie .	Gold . . .	P. L. .	4,941	1st April, 1915.	Do.
Do.	(97) Do. . .	Do. . . .	P. L. .	640	12th August, 1915.	Do.
Northern Shan States	(98) Messrs. Mohochang Exploration Co., Ltd.	Gold, silver, lead, iron and zinc.	P. L. (renewal).	3,200	9th April, 1915.	Do.
Do. .	(99) The Burma Corporation, Ltd.	Copper, galena and allied minerals.	P. L. (renewal).	2,560	23rd July, 1915.	Do.
Pakokku	(100) Messrs. The Singu (Burma) Oil Syndicate.	Mineral oil . .	P. L. (renewal).	76·80 and 371·20 acres.	14th November, 1915.	Do.
Do. .	(101) Messrs. The Burma Oil Co., Ltd.	Do. . .	P. L. (renewal).	351·63 acres Block D2 of the Yenangyat Oil Field.	24th July, 1915.	Do.
Do. .	(102) Messrs. The British-Burma Petroleum Co., Ltd.	Do. . .	P. L. (renewal).	614·40 and 261 acres.	23rd July, 1915.	Do.
Prome .	(103) The Burma Oil Co., Ltd.	Do. . .	P. L.	3,200	7th June, 1915.	Do.
Do.	(104) Maung Gyi . .	Do. . .	P. L. (renewal).	1,862	5th March, 1915.	Do.
Sagaing .	(105) C. Soon Thin	Do. .	P. L. (renewal).	3,190	13th February, 1914.	Do.

P. L.=*Prospecting License*. M. L.=*Mining Lease*.

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Shwebo .	(106) Mr. D'Ortez .	All minerals (except oil).	P. L. (renewal).	3,200	30th June, 1915.	1 year.
Southern Shan States.	(107) Mr. A. C. Martin .	Do. .	P. L. .	2,560	9th June, 1915.	Do.
Do. .	(108) Maung Yaing .	Lead and silver .	M. L. .	18·75	20th July, 1914.	5 years.
Do. .	(109) Mr. J. R. Browne .	All minerals (except oil).	P. L. .	1,120	28th June, 1915.	1 year.
Do. .	(110) Messrs. Jamal Bros. & Co., Ltd.	Do. .	P. L. .	5,446	26th June, 1915.	Do.
Do. .	(111) Maung Pan Aung .	Do. .	P. L. .	640	14th August, 1915.	Do.
Do. .	(112) E. E. Moola .	Wolfram .	P. L. .	640	19th July, 1915.	Do.
Do. .	(113) Mr. R. E. Smith .	All minerals (except oil).	P. L. (renewal).	3,040	15th June, 1915.	Do.
Do. .	(114) Ko Law Pan .	Do. .	P. L. (renewal).	360	21st August, 1915.	Do.
Do. .	(115) Do. . .	Do. .	P. L. (renewal).	1,600	4th September, 1915.	Do.
Do. .	(116) Capt. John Terndrup.	Do. .	P. L. .	472·5	5th October, 1915.	Do.
Do. .	(117) The Hon'ble Mr. Lim Chin Tsong.	Do. .	P. L. .	166	20th November, 1915.	Do.
Do. .	(118) Mr. A. C. Martin .	Do. .	P. L. .	3,007·5	14th December, 1915.	Do.
Do. .	(119) Do.	Do. .	P. L. .	640	Do. .	Do.
Tavoy .	(120) Mr. Greenhow	Do. .	P. L. .	2,500	28th January, 1915.	Do.
Do. .	(121) Mrs. C. F. Aubrey .	Do. .	P. L. .	2,570	27th March, 1915.	Do.
Do.	(122) Mr. C. W. Chater .	Do. .	P. L. .	6	25th March, 1915.	Do.
Do. .	(123) Khoo Tun Byan .	Do. .	P. L. .	64	6th March, 1915.	Do.
Do. .	(124) Messrs. The Wagon Pachaung Wolfram Mines, Ltd.	Do. .	P. L. (renewal).	2,600	3rd December, 1912.	(*a*)
Do. .	(125) Kyong Nga . .	Do. .	P. L. (renewal).	2,048	30th January, 1915.	1 year.
Do. .	(126) The Bombay Tavoy Mining Co.	Do. .	P. L. (renewal).	2,845·32	4th November, 1913.	(*a*)
Do. .	(127) Maung Hpaw .	Do. .	P. L. (renewal).	2,745·60	24th November, 1913.	(*a*)
Do. .	(128) Messrs. Radcliff & Co., Ltd.	Do. .	P. L. (renewal).	4,320	30th December, 1913.	(*a*)

P. L.=*Prospecting License.* M. L.=*Mining Lease.*
(*a*) Period extended under rule 30 (1) proviso, pending the grant of a mining lease.

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Tavoy .	(129) Maung Hpaw .	All minerals (except oil).	P. L. (renewal).	3,098·29	25th November, 1913	(*a*)
Do. .	(130) Quah Cheng Guan.	Do. .	P. L. (renewal).	271·36	23rd December, 1913.	(*a*)
Do. .	(131) Khoo Tun Byan .	Do.	P. L. (renewal).	3,086	24th January, 1914.	(*a*)
Do. .	(132) Ma Sein Daing .	Do. .	P. L. (renewal).	500	2nd February, 1915.	1 year.
Do. .	(133) Mr. T. Fowle .	Do. .	P. L. (renewal).	4,478	10th February, 1914.	(*a*)
Do. .	(134) Teong Swee Sin .	Do. .	P. L. (renewal).	1,132	8th March, 1914.	(*a*)
Do. .	(135) Tavoy Concessions, Ltd.	Do. .	P. L. (renewal).	2,086	9th September, 1913.	(*a*)
Do. .	(136) Kyong Nga . .	Do. .	P. L. (renewal).	2,846	27th May, 1913.	(*a*)
Do. .	(137) Tavoy Concessions, Ltd.	Do. .	P. L. (renewal).	2,943	28th February, 1914.	(*a*)
Do. .	(138) Quah Cheng Gwan	Do. .	P. L. (renewal).	720	11th December, 1914.	1 year.
Do. .	(139) Mr. H. P. Selvey .	Do. .	P. L. (renewal).	737	12th February, 1915.	Do.
Do. .	(140) Maung Shwe Pu .	Do. .	P. L. .	813	25th August, 1915.	Do.
Do. .	(141) Quah Cheng Gwan	Do. .	P. L. .	1,429	26th August, 1915.	Do.
Do. .	(142) Maung E. Lin .	Do. .	P. L. .	1,674	23rd August, 1915.	Do.
Do. .	(143) Do. .	Do. .	P. L. .	100	30th July, 1915.	Do.
Do. .	(144) Quah Cheng Gwan.	Do. .	P. L. .	300	26th August, 1915.	Do.
Do. .	(145) Mr. H. P. Selvey, Lim Kyee Yan and Ma Sein Daing.	Do. .	P. L. .	640	28th September, 1915.	Do.
Do. .	(146) Maung Ni . .	Do. .	P. L. .	2,988	11th September, 1915.	Do.
Do. .	(147) Maung Lun Bin .	Do. .	P. L. .	2,064	6th September, 1915.	Do.
Do. .	(148) Mr. H. P. Selvey and Lim Kyee Yan.	Do. .	P. L. .	320	28th September, 1915.	Do.
Do. .	(149) L. M. Ismail .	Do. .	P. L. .	455	29th September, 1915.	Do.
Do. .	(150) Maung Lu Pe .	Do. .	P. L. (renewal).	200	18th February, 1915.	Do.
Do. .	(151) Messrs. Radcliff & Co., Ltd.	Do. .	P. L. (renewal).	390	22nd July, 1915.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*
(*a*) Period extended under rule 30 (1) proviso, pending the grant of a mining lease.

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Tavoy	(152) Mr. J. C. Cross .	All minerals (except oil).	P. L. .	1,280	6th October, 1915.	3 months.
Do. .	(153) Maung Min Gyaw Bros. & Co.	Do. .	P. L. .	665	22nd December, 1915.	Do.
Do. .	(154) Mrs. L. Penna and Maung Ni Toe.	Do. .	P. L. .	972	2nd October, 1915.	1 year.
Do. .	(155) Mr. John J. A. Page	Do. .	P. L. .	538	6th December, 1915.	6 months.
Do. .	(156) Do. .	Do. .	P. L. .	256	Do.	Do.
Do. .	(157) Maung Maung .	Do. .	P. L. .	798·72	7th October, 1915.	Do.
Do. .	(158) Mr. H. G. Mathews	Do. .	P. L. .	538	2nd November, 1915.	Do.
Do. .	(159) Ong Hoe Kyin .	Do.	P. L. .	519	4th October, 1915.	1 year.
Do. .	(160) Maung Maung .	Do. .	P. L. .	1,280	5th October, 1915.	Do.
Do. .	(161) Eu Shwe Swe .	Do. .	P. L. .	217	20th October, 1915.	6 months.
Do. .	(162) Messrs. P. M. Illingworth, W. P. Leal and W. Ross.	Do. .	P. L. .	1,504	18th November, 1915.	Do.
Do. .	(163) Lim Shain . .	Do. .	P. L. (renewal)	1,000	2nd September, 1915.	1 year.
Do. .	(164) Tan Chong Yean .	Do. .	P. L. (renewal).	275	9th November, 1915.	3 months.
Thaton .	(165) Messrs. A. V. Joseph & Co.	Wolfram . .	P. L. (renewal).	1,600	17th October, 1914.	1 year.
Do. .	(166) Mr. H. E. Singleton	All minerals (except oil).	P. L. .	320	13th October, 1915.	Do.
Do. .	(167) Ma Nyein . .	Do. .	P. L. .	704	11th October, 1915.	Do.
Do. .	(168) Foo Ban Seng .	Do. .	P. L. .	640	18th December, 1915.	Do.
Thayetmyo.	(169) Mr. J. A. Murray .	Mineral oil .	P. L. (renewal).	3,840	26th November, 1914.	1 year.
Do. .	(170) The Burma Oil Co., Ltd.	Do. .	P. L. .	4,480	19th April, 1915.	Do.
Do. .	(171) Do. .	Do. .	P. L. (renewal).	1,920	26th April, 1915.	Do.
Do. .	(172) Do. .	Do. .	P. L. (renewal).	960	6th June, 1915	Do.
Do. .	(173) Mr. J. A. Murray	Do. .	P. L. .	1,920	1st November, 1915.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*concld.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Thayetmyo .	(174) Messrs. The Burma Oil Co., Ltd.	Mineral oil .	P. L. (renewal).	1,440	28th September, 1915.	1 year.
Do. .	(175) Do. .	Do. .	P. L. (renewal).	3,840	24th September, 1915.	Do.
Upper Chindwin.	(176) The Indo-Burma Petroleum Co., Ltd.	Do. .	P. L. (renewal).	3,200	1st October, 1915.	Do.

CENTRAL PROVINCES.

Balaghat .	(177) Indian Mineral Mining Syndicate.	Manganese .	M. L. .	7	5th January, 1915.	5 years.
Do. .	(178) Hon'ble Mr. M. B. Dadabhoy, C.I.E.	Do. .	P. L. .	2	18th January, 1915.	1 year.
Do. .	(179) Hon'ble Sir Kasturchand Daga, K.C.I.E.	Do. .	P. L. (renewal).	743	11th September, 1913.	2 years.
Do. .	(180) Mr. Lakshman Rao Naidu.	Do. .	P. L. .	289	25th June, 1915.	1 year.
Do. .	(181) Netra Manganese Co., Ltd.	Do. .	P. L. .	110	7th April, 1915.	Do.
Do. .	(182) Do. .	Do. .	P. L. .	169	3rd May, 1915.	Do.
Do. .	(183) Babu Kripa Shankar	Do. .	P. L. .	118	25th June, 1915.	Do.
Do. .	(184) Do. .	Do.	P. L. .	14	7th June, 1915.	Do.
Do. .	(185) Mr. Rewa Shankar	Do. .	P. L. .	3	Do.	Do.
Do. .	(186) Do. .	Do. .	P. L. .	72	Do.	Do.
Do. .	(187) Babu Kripa Shankar	Do. .	P. L. (renewal).	54	17th June, 1915.	6 months.
Do. .	(188) Mr. P. Balkrishna Naidu.	Do. .	P. L. .	21	23rd August, 1915.	1 year.
Do. .	(189) Babu Kripa Shankar	Do. .	M. L. .	532	7th July, 1915.	30 years.
Do. .	(190) Do. .	Do. .	P. L. .	376	8th July, 1915.	1 year.
Do. .	(191) Mr. S. Lakshman Rao Naidu.	Do. .	P. L. .	2	Do.	Do.
Do. .	(192) Do. .	Do. .	P. L. .	29	Do.	Do.
Do.	(193) Do. .	Do. .	P. L. .	67	27th July, 1915.	Do.
Do. .	(194) Indian Manganese Co., Ltd.	Do. .	P. L. .	40	23rd August, 1915.	Do.
Do. .	(195) Do. .	Do. .	P. L. .	54	Do.	Do.
Do. .	(196) Diwan Bahadur Sir Kasturchand Daga, K.C.I.E.	Do. .	P. L. .	14	21st September, 1915.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

CENTRAL PROVINCES—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Balaghat	(197) Babu Kripa Shankar	Manganese	P. L. (renewal).	54	17th June, 1915.	1 year.
Do.	(198) Diwan Bahadur Sir Kasturchand Daga, K.C.I.E.	Do.	P. L. (renewal).	743	11th September, 1915.	6 months.
Do.	(199) Mr. T. D. Ramchandra Naidu.	Do.	P. L.	346	5th October, 1915.	1 year.
Do.	(200) Do.	Do.	P. L.	374	Do.	Do.
Do.	(201) Messrs. Goredutt, Ganesh Lal and M. D'Costa.	Do.	P. L.	3	Do.	Do.
Do.	(202) Netra Manganese Co., Ltd.	Do.	M. L.	19	30th June, 1915.	30 years.
Do.	(203) Hon'ble Sir Kasturchand Daga, K.C.I.E.	Do.	M. L.	169	9th October, 1915.	Do.
Do.	(204) Do.	Do.	P. L.	3	30th October, 1915.	1 year.
Bhandara	(205) Mr. Lakshman Damodar Lele.	Do.	M. L.	83	9th December, 1914.	3 years.
Do.	(206) Seth Mahadeo	Do.	P. L.	314	10th March, 1915.	1 year.
Do.	(207) Seth Gowardhandas	Do.	P. L.	74	2nd February, 1915.	Do.
Do.	(208) Messrs. Lalbehari Narayandas and Ramcharan Shankarlal.	Do.	M. L.	35	16th January, 1915.	8 years.
Do.	(209) Messrs. Motilal and Ramnarayan.	Do.	P. L.	66	4th January, 1915.	1 year.
Do.	(210) Mr. Mahanandram Sheonarayan.	Do.	P. L.	21	Do.	Do.
Do.	(211) Seth Gowardhandas	Do.	P. L.	159	6th February, 1915.	Do.
Do.	(212) Do.	Do.	P. L.	29	Do.	Do.
Do.	(213) Nagpur Manganese Mining Syndicate.	Do.	P. L.	32	8th April, 1915.	Do.
Do.	(214) Messrs. Ratanchand Kesrichand Chullaney & Sons.	Do.	P. L.	53	27th April, 1915.	Do.
Do.	(215) Hon'ble Sir Kasturchand Daga, K.C.I.E.	Do.	P. L.	16	3rd May, 1915.	Do.
Do.	(216) Seth Gowardhandas	Do.	P. L.	20	14th June, 1915.	Do.
Do.	(217) Do.	Do.	P. L.	17	25th May, 1915.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

CENTRAL PROVINCES—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Bhandara .	(218) Seth Gowardhandas	Manganese .	P. L. (renewal).	96	22nd April, 1915.	2 months.
Do. .	(219) Do. .	Do. .	P. L. (renewal).	47	Do.	Do.
Do. .	(220) Seth Mahadeo .	Do. .	M. L. .	257	15th May, 1915.	30 years.
Do. .	(221) Khan Bahadur Byramji Pestonji.	Do. .	P. L. .	13	5th July, 1915.	1 year.
Do. .	(222) Diwan Bahadur Sir Kasturchand Daga, K. C. I. E.	Do. .	P. L. .	87	21st July, 1915.	Do.
Do. .	(223) Seth Gowardhandas	Do. .	P. L. .	47	5th August, 1915.	Do.
Do. .	(224) Do. .	Do. .	P. L. (renewal)	270	2nd July, 1915.	7 months.
Do. .	(225) Do. .	Do. .	P. L. .	19	29th November, 1915.	1 year.
Do. .	(226) Pandit Rewa Shanker.	Do. .	P. L. .	217	23rd December, 1915.	Do.
Chanda .	(227) Chanda Coal Prospecting Syndicate.	Coal . . .	M. L. .	776	1st April, 1915.	Will expire with the original lease, dated the 4th April 1913, to which it is supplementary.
Do. .	(228) Hon'ble Sir Kasturchand Daga, K.C.I.E., and the Hon'ble Mr. M. B. Dadabhoy, C.I.E.	Do. . .	M. L. .	151	14th May, 1915.	Will expire with the original lease, dated the 5th April 1913, to which it is supplementary.
Do. .	(229) Messrs. K. Verma and Kanhaiyalal.	Do. . .	M. L. .	1,064	30th October, 1915.	30 years.
Do. .	(230) Tata Iron & Steel Co., Ltd.	Iron . .	M. L. .	144	22nd October, 1915.	Will expire with the original lease, dated the 17th December 1906, to which it is supplementary.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

CENTRAL PROVINCES—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Chhindwara	(231) Messrs. Shaw Wallace & Co.	Coal . .	P. L. .	2,218	15th January, 1915.	1 year.
Do. .	(232) Messrs. H. Verma and Kanhaiyalal.	Do. . .	M. L. .	789	23rd March, 1915.	30 years.
Do. .	(233) Do. .	Manganese .	M. L. .	150	Do.	10 years.
Do. .	(234) Hon'ble Mr. M. B. Dadabhoy, C.I.E.	Do. .	M. L. .	32	7th April, 1915.	5 years.
Do. .	(235) Messrs. Byramji Pestonji & Co.	Do. .	P. L. .	203	9th April, 1915.	1 year.
Do. .	(236) Indian Manganese Co., Ltd.	Do. .	P. L. .	10	14th August, 1915.	Do.
Do. .	(237) Messrs. Shaw Wallace & Co.	Coal .	P. L. (renewal).	1,193	1st October, 1915.	Do.
Do. .	(238) Hon'ble Mr. M. B. Dadabhoy, C.I.E.	Manganese .	M. L. .	25	7th October, 1915.	30 years.
Do. .	(239) Hon'ble Sir Kasturchand Daga, K.C.I.E.	Do. .	P. L. .	172	5th November, 1915.	1 year.
Jubbulpore.	(240) Mr. P. C. Dutt .	Bauxite .	M. L. .	214	11th January, 1915.	30 years.
Do. .	(241) Mr. George Forrester.	Manganese, Gold, Silver and Copper.	P. L. .	653	20th January, 1915.	1 year.
Do. .	(242) Messrs. H. F. Cook & Sons.	Bauxite . .	M. L. .	25	30th January, 1915.	30 years.
Do. .	(243) Mr. P. C. Dutt .	Manganese and Iron.	M. L. .	55	4th September, 1915.	Do.
Do. .	(244) Do. .	Bauxite . .	P. L. .	31	10th September, 1915.	1 year.
Do. .	(245) Messrs. Hiralal Ghansiamdas.	Soapstone . .	M. L. .	76	5th September, 1915.	30 years.
Do. .	(246) Mr. P. C. Dutt .	Iron and Bauxite.	P. L. (renewal).	281	22nd October, 1915.	1 year.
Nagpur .	(247) Mr. Lakshman Damodar Lele.	Manganese .	P. L. .	140	23rd February, 1915.	Do.
Do. .	(248) Nagpur Manganese Mining Syndicate.	Do. .	P. L. .	30	6th January, 1915.	Do.
Do. .	(249) Do. .	Do. .	P. L. .	67	Do.	Do.
Do. .	(250) Mr. Ramkrishnapuri Gosai.	Manganese and Coal.	P. L. .	405	27th January, 1915.	Do.
Do. .	(251) Do. .	Manganese .	P. L. .	75	25th June, 1915.	Do.
Do. .	(252) Mr. Lakshman Damodar Lele.	Do. .	P. L. .	157	4th June, 1915.	Do.
Do. .	(253) Nagpur Manganese Mining Syndicate.	Do. .	M. L. .	11	18th March, 1915.	3 years.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

CENTRAL PROVINCES—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Nagpur .	(254) Messrs. Goredutt, Ganeshlal and M. D'Costa.	Manganese .	P. L. .	163	7th May, 1915.	1 year.
Do. .	(255) Ramkrishnapuri Gosai.	Do. .	P. L. .	47	29th May, 1915.	Do.
Do. .	(256) Do. .	Galena .	P. L. .	184	25th June, 1915.	Do.
Do. .	(257) Nagpur Manganese Mining Syndicate.	Manganese .	M. L. .	127	18th March, 1915.	5 years.
Do. .	(258) Do. .	Do. .	M. L. .	49	Do.	Do.
Do. .	(259) Mr. Asaram Chandrabhan.	Do. .	P. L. .	94	30th June, 1915.	1 year.
Do. .	(260) Mr. Lakshman Damodar Lele.	Do. .	P. L. (renewal).	130	1st May, 1915.	Do.
Do. .	(261) Mr. S. Lakshman Rao Naidu.	Do. .	P. L. .	599	6th July, 1915.	Do.
Do. .	(262) Hon'ble Mr. M. B. Dadabhoy, C.I.E.	Do. .	P. L. .	297	16th September, 1915.	Do.
Do. .	(263) Rao Sahib D. Lakshminarayan.	Do. .	M. L. .	63	26th July, 1915.	5 years.
Do. .	(264) Mr. Mohanlal Kalar	Do. .	P. L. .	4	16th September, 1915.	1 year.
Do. .	(265) Khan Bahadur Byramji Pestonji.	Do. .	P. L. .	602	27th September, 1915.	Do.
Do. .	(266) Indian Manganese Co., Ltd.	Do. .	P. L. .	248	16th September, 1915.	Do.
Do. .	(267) Babu Madhulal Dugar.	Do. .	P. L. .	1,613	3rd November, 1915.	Do.
Do. .	(268) Gosai Ramkrishnapuri.	Galena .	P. L. (renewal).	125	13th October, 1915.	6 months.
Do. .	(269) Do. .	Do. .	P. L. .	18	Do.	Do.
Do. .	(270) Do. .	Do. .	P. L. .	33	Do.	Do.
Do. .	(271) Messrs. Goredutt, Ganeshlal and M. D'Costa.	Manganese .	P. L. .	726	5th November, 1915.	1 year.
Do. .	(272) Messrs. Ramprasad and Lakshminarayan.	Do. .	P. L. .	163	11th October, 1915.	Do.
Do. .	(273) Rai Bahadur Bansilal Abirchand Mining Syndicate.	Do. .	P. L. .	147	9th October, 1915.	Do.
Do. .	(274) Messrs. Balibhadra and Mahanlal.	Do. .	M. L. .	16	11th November, 1915.	5 years.
Nimar .	(275) Rao Bahadur Rajaram Sitaram Dikshit.	Lead, Copper and Silver.	P. L. .	358	9th October, 1915.	1 year.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

CENTRAL PROVINCES—*concld.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Yeotmal .	(276) Hon'ble Sir Kasturchand Daga, K.C.I.E.	Coal . .	P. L. .	8,716	5th May, 1915.	1 year.
Do. .	(277) Hon'ble Mr. M. B. Dadabhoy, C.I.E.	Do. . .	P. L. .	5,217	5th March, 1915.	Do.
Do. .	(278) Do. .	Do. . .	P. L. .	2,812	Do.	Do.
Do. .	(279) Mulla Hasan Ali Nathubhoy.	Do. . .	P. L. .	3,839	18th March, 1915.	Do.
Do. .	(280) Hon'ble Mr. M. B Dadabhoy, C.I.E.	Do. . .	P. L. .	372	15th October, 1915.	Do.

MADRAS.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Bellary .	(281) A. D. Sanders, Esq., Mining Engineer, Ramandrug.	Manganese and Iron-ores.	P. L. .	46·30	21st September, 1915.	1 year.
Kurnool .	(282) A. Ghose, Esq. .	Diamond . .	M. L. .	545·42	15th October, 1914.	30 years.
Nellore .	(283) M. R. Ry. M. R. M. A. Subrahmaniyam Chettiyar.	Mica . . .	M. L. .	22·23	5th August, 1911.	30 years.
Do. .	(284) R. Ramanma, widow of Katem Reddi Penchal Reddi.	Do. . . .	M. L. .	23·70	1st October, 1914.	Do.
Do. .	(285) Khan Bahadur Muhammad Safdar Husain, Khan Sahib.	Do. .	P. L. .	20·78	1st March, 1915.	1 year.
Do. .	(286) Do. .	Do. . . .	P. L. .	83·70	Do.	Do.
Do. .	(287) M. R. Ry. Kallcheti Penchalu Reddi.	Do. . .	P. L. .	17·76	Do.	Do.
Do. .	(288) Hajee Muhammad Badsha Sahib & Co.	Do. . .	M. L. .	4·42	1st April, 1915.	30 years.
Do. .	(289) Errabaka Venkatarami Reddi.	Do. . . .	M. L. .	8·85	Do.	20 years.
Do. .	(290) Gurjala Subramaniam.	Do. . .	M. L. .	88·79	Do.	30 years.
Do. .	(291) Balakavi Pedda Chanchayya.	Do. . . .	M. L. .	31·57	1st March, 1915.	Do.
Do. .	(292) A. M. Jeevanjee & Co.	Do. . . .	P. L. .	67·22	15th August, 1915.	1 year.
Do. .	(293) Messrs. F. F. Chrestien & Co.	Do. . . .	P. L. .	88·34	15th June, 1915.	Do.
Do. .	(294) P. K. Vengama Nayudu.	Do. . . .	P. L. .	83·40	10th August, 1915.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

MADRAS—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area. in acres.	Date of commencement.	Term.
Nellore .	(295) S. Guanamuthu Nadar.	Mica . . .	M. L. .	2·27	4th August, 1915.	20 years.
Do. .	(296) K. Penchalu Reddi	Do. . . .	P. L. .	26·50	20th November, 1915.	1 year.
Do. .	(297) Messrs. F. F. Chrestien & Co.	Do.. . .	P. L. .	52·00	5th August, 1915.	Do.
Salem .	(298) Messrs. Gaudart & Co.	Iron-ore . .	M. L. .	4,369	8th October, 1914.	30 years.
Do. .	(299) Messrs. Hajee Ismail Sait and Sons.	Magnesite . .	P. L. .	358·44	26th January, 1915.	1 year.
South Canara.	(300) Mr. T. Pinto .	Corundum . .	M. L.	190·02	1st September, 1915.	30 years.
Tinnevelly .	(301) A. Sankarakumaru Chettiyar of Kottar Nagarkoil.	Garnet Sand .	P. L. .	2·10	9th March, 1915.	1 year.

NORTH-WEST FRONTIER PROVINCE.

Hazara .	(302) Messrs. T. H. Chuhar Lal and Sons, Bankers, Abbottabad.	Coal . . .	P. L. .	11·76	25th May, 1915.	1 year.
Do. .	(303) Do. .	Lead . . .	P. L. .	0·14	4th December, 1915.	Do.

PUNJAB.

Attock .	(304) Attock Oil Company	Oil . . .	P. L. .	640	19th June, 1915.	1 year.
Do. .	(305) Do. .	Do. . . .	P. L. .	2,880	17th August, 1915.	Do.
Do. .	(306) Do. .	Do. . . .	P. L. .	15,360	Do.	Do.
Do. .	(307) Do. .	Do. . . .	P. L. .	2,560	Do.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

SUMMARY.

Provinces.	Prospecting Licenses.	Mining Leases.	Total of each Province.
Assam	3	..	3
Baluchistan	..	7	7
Bengal	1	..	1
Bihar and Orissa	13	2	15
Burma	147	3	150
Central Provinces	80	24	104
Madras	11	10	21
North-West Frontier Province	2	..	2
Punjab	4	..	4
Totals for each kind and Grand Total, 1915	261	46	307
TOTAL FOR 1914	305	58	363

CLASSIFICATION OF LICENSES AND LEASES.

TABLE 35.—*Prospecting Licenses granted in Assam during 1915.*

District.	1915. No.	1915. Area in acres.	1915. Mineral.
Khasi and Jaintia Hills	1	12,704	Gold and certain other allied minerals.
Do.	1	12,704	Tin and wolfram.
Do.	1	8,160	Gold, tin and certain other minerals.
TOTAL	3	..	

TABLE 36.—*Mining Leases granted in Baluchistan during 1915.*

District.	1915. No.	1915. Area in acres.	1915. Mineral.
Kalat	1	80	Coal.
Quetta	1	169·76	Do.
Sibi	2	160	Do.
Zhob	3	240	Chromite.
TOTAL	7	..	

TABLE 37.—*Prospecting License granted in Bengal during 1915.*

District.	1915. No.	1915. Area in acres.	1915. Mineral.
Chittagong	1	4,000	Mineral oil.

TABLE 38.—*Prospecting Licenses and Mining Leases granted in Bihar and Orissa during 1915.*

District.	1915. No.	1915. Area in acres.	1915. Mineral.
Prospecting Licenses.			
Hazaribagh	1	80	Mica.
Palamau	1	6,119	Coal.
Sambalpur	1	882·78	Mica.
Singhbhum	1	6·5	Gold.
Do.	1	320	Gold, manganese and bauxite.
Do.	4	496·40	Manganese.
Do.	1	1,267·2	Iron-ore.
Do.	3	5,684·56	Chromite.
TOTAL .	13	..	
Mining Leases.			
Sambalpur	1	720·2	Coal.
Singhbhum	1	2,035·20	Iron-ore.
TOTAL .	2	..	

TABLE 39.—*Prospecting Licenses and Mining Leases granted in Burma during 1915.*

DISTRICT.	1915. No.	1915. Area in acres.	1915. Mineral.
Prospecting Licenses.			
Akyab]	1	3,620	Mineral oil.
Amherst	7	8,477·6	All minerals (except oil).
Do.	1	640	Tin, wolfram, gold, silver, copper and antimony.
Bhamo	1	5,517	All minerals (except oil).
Katha	2	7,596·80	Tin, wolfram, gold, silver and copper.
Do.	1	960	Zinc, lead and silver.
Do.	1	23,568·64	Tin, wolfram, silver, copper, lead, zinc and gold.
Kyaukse	2	14,893	All minerals (except oil).
Lower Chindwin	2	2,940	Copper, tin, lead, zinc, silver and gold.
Do.	1	1,440	Copper.
Magwe	1	2,240	Mineral oil.
Mergui	33	47,854·70	All minerals (except oil).
Minbu	8	6,391·60	Mineral oil.
Myingyan	1	640	Do.
Myitkyina	1	1,440	Gold and platinum.
Do.	3	2,080	Gold, platinum and allied metals.
Do.	1	1,466	Gold and other minerals (except oil).
Do.	2	5,581	Gold.
Northern Shan States	1	3,200	Gold, silver, lead, iron and zinc.
Do.	1	2,560	Copper, Galena and allied minerals.
Pakôkku	3	1,042·83	Mineral oil.
Prome	2	5,062	Do.
Sagaing	1	3,190	Do.
Shwebo	1	3,200	All minerals (except oil)
Southern Shan States	11	19,046	Do.
Do.	1	640	Wolfram.
Tavoy	45	62,812·29	All minerals (except oil).
Thaton	1	1,600	Wolfram.
Do.	3	1,664	All minerals (except oil).
Thayetmyo	7	18,400	Mineral oil.
Upper Chindwin	1	3,200	Do.
TOTAL	147	..	

TABLE 39.—*Prospecting Licenses and Mining Leases granted in Burma during 1915*—contd.

DISTRICT.	1915. No.	1915. Area in acres.	1915. Mineral.
Mining Leases.			
Minbu	2	3,153·40	Mineral oil.
Southern Shan States	1	18·75	Lead and silver.
TOTAL	3	..	

TABLE 40.—*Prospecting Licenses and Mining Leases granted in the Central Provinces during 1915.*

DISTRICT.	1915. No.	1915. Area in acres.	1915. Mineral.
Prospecting Licenses.			
Balaghat	24	3,700	Manganese.
Bhandara	19	1,597	Do.
Chindwara	2	3,411	Coal.
Do.	3	385	Manganese.
Jubbulpore	1	653	Manganese, gold, silver and copper.
Do.	1	31	Bauxite.
Do.	1	281	Iron and bauxite.
Nagpur	18	5,302	Manganese.
Do.	1	495	Manganese and coal.
Do.	4	360	Galena.
Nimar	1	358	Lead, copper and silver.
Yeotmal	5	20,956	Coal.
TOTAL	80	..	

TABLE 40.—*Prospecting Licenses and Mining Leases granted in the Central Provinces during 1915*—contd.

DISTRICT.	1915.		
	No.	Area in acres.	Mineral.
Mining Leases.			
Balaghat	4	727	Manganese.
Bhandara	3	375	Do.
Chanda	4	2,135	Coal.
Chhindwara	1	789	Do.
Do.	3	207	Manganese.
Jubbulpore	2	239	Bauxite.
Do.	1	55	Manganese and iron.
Do.	1	76	Soapstone.
Nagpur	5	266	Manganese.
TOTAL	24	..	

TABLE 41.—*Prospecting Licenses and Mining Leases granted in Madras during 1915.*

DISTRICT.	1915.		
	No.	Area in acres.	Mineral.
Prospecting Licenses.			
Bellary	1	46·30	Manganese and iron-ores.
Nellore	8	439·70	Mica.
Salem	1	358·44	Magnesite.
Tinnevelly	1	2·10	Garnet sand.
TOTAL	11	..	

TABLE 41.—*Prospecting Licenses and Mining Leases granted in Madras during 1915*—contd.

DISTRICT.	1915.		
	No.	Area in acres.	Mineral.
Mining Leases.			
Kurnool	1	545·42	Diamond.
Nellore	7	181·83	Mica.
Salem	1	4,369	Iron-ore.
South Canara	1	190·02	Corundum.
TOTAL	10	..	

TABLE 42.—*Prospecting Licenses granted in the North-West Frontier Province during 1915.*

DISTRICT.	1915.		
	No.	Area in acres.	Mineral.
Hazara	1	11·76	Coal.
Do.	1	6·14	Lead.
TOTAL	2	..	

TABLE 43.—*Prospecting Licenses granted in the Punjab during 1915.*

DISTRICT.	1915.		
	No.	Area in acres.	Mineral.
Attock	4	21,440	Oil.

FLEMINGOSTREA, AN EASTERN GROUP OF UPPER CRETACEOUS AND EOCENE *OSTREIDÆ*: WITH DESCRIPTIONS OF TWO NEW SPECIES. BY ERNEST W. VREDENBURG, *Superintendent, Geological Survey of India.* (With Plates 17 to 20.)

IN their description of the lamellibranchiata forming the second instalment, shortly to be published, of their monograph on the lower eocene fauna of the Ranikot of Sind, Messrs. Cossman and Pissarro have recorded, under the name of *Ostrea Haydeni*, a species related to the remarkable *Ostrea Flemingi* d'Archiac and Haime, from the middle eocene of the Salt Range. In addition to the form described by our distinguished colleagues, I have noticed, amongst some stray specimens, another species of the same group which had escaped their attention and which is described below as *Ostrea Kalhora*. A comparison of all these forms with the available material in the hands of the Geological Survey in Calcutta indicates that they are related also to another remarkable species discovered by Dr. Noetling in the upper Cretaceous of the Des valley in Baluchistan (*General Report*, G. S. I., 1898-99, p. 55).

The characters common to all these species are: a small or medium size, a tendency to an equilateral shape, with concentrically foliaceous valves never greatly contrasted and often quite similar; there is no distinct trace of a surface of adherence; the umbo is small, subcentral, exogyroid only in its embryonic portion, the hinge small, the muscular scar transverse inferiorly and posteriorly situated; the pallial punctations and crenulations are feeble or absent.

These thin-shelled forms with their small umbo, and their transverse muscular scar inferiorly and posteriorly situated, can scarcely find place in the sub-genus *Gryphæa* or any of its sections. They do not exhibit any resemblance to *Gryphæa* s. str., the type of which is *Gr. angulata* Lamk., which is very inequivalve with a very prominent spirally coiled umbo in the left valve. They are not in any way related to *Pycnodonta*, the type of which is the ponderous *Gryphæa vesicularis* and which includes extremely inequivalve forms with pronounced pallial pits and crenulations,

and with an orbicular muscular scar situated at a considerable distance from the inferior margin and often subcentral. It seems that they might be conveniently grouped together in a sub-genus *Flemingostrea* of which *Ostrea Flemingi,* may be taken as the type and which might include the following species:—

Ostrea Morgani n. sp.
" *Haydeni* n. sp., Cossmann and Pissarro.
" *Kalhora,* n. sp.
" *Flemingi* d'Archiac and Haime.

Ostrea heteroclita Defrance, from the Thanetian and Sparnacian of the Paris basin, also occurring in the lowest beds of the upper Ranikot in Sind, may also belong to this group, though it seems at times, yet by no means generally, to be fixed by a rather large surface in consequence of its gregarious habit, while the other species above-named are remarkable for the absence of any visible point of attachment.

The oldest species, *O. Morgani,* occurs in the uppermost zone of the Maestrichtian of Baluchistan in the last horizon with abundant ammonites. *Ostrea Kalhora* and *Ostrea Haydeni* occur in the lower eocene (Ranikot) of Sind, while *O. Flemingi* occurs in the Salt Range in beds of Laki age, and has been met with in strata probably of the same age in Tibet.

The proposed sub-genus, or section, *Flemingostrea* does not appear to have survived the eocene. It was already in existence in Upper Cretaceous times. The ancestry of these curious forms should therefore be sought somewhat lower in the Cretaceous. Amongst all the Cretaceous forms described by Coquand, the only one that appears to exhibit some resemblance to the fossils here described is *O. Bourguignati* Coqu. from the Santonian of France and of North Africa (especially the specimens illustrated on Pl. XXI of Coquand's monograph).

Ostrea Morgani and *O. Kalhora* are here described for the first time, and it has been thought useful to have *O. Flemingi* figured afresh.

OSTREA (FLEMINGOSTREA) MORGANI n. sp.

Pl. 17, 18.

1899. *Ostrea* sp., Noetling, Gen. Rep. G. S. I. for 1898-99, p. 55.

Description.—Small to medium, equilateral, broadly triangular, with pointed umbo on either side of which the approximately recti-

linear margins converge towards the apex at an angle of about 76° to 78° while inferiorly they are joined by a rounded curve with the greatly expanded inferior margin. The left valve which is more convex than the right and which shows no trace of a surface of adherence is raised along its median region into a roof-shaped swelling often bordered by a broad groove on one side, more especially the posterior side, or on both. This structure affects the lower margin in such a manner that the junction of the valves exhibits a sinus analogous to that of a brachiopod. The right valve, on approaching the inferior margin, often shows a broad depression corresponding with the roof-shaped swelling of the left valve. Both valves are similarly ornamented with numerous slightly wavy, concentric, foliaceous lamellæ. The foliaceous structure is especially conspicuous in the case of the specimens collected in the uppermost Maestrichtian of the Des valley. The collections from the same horizon at Mazar Drik have yielded a solitary specimen of a left valve remarkable for the wide spacing of the concentric ripples, a peculiarity which seems partly due to the mode of fossilisation; the outer surface is less exfoliated than usual, so that the layers of growth which increase the wrinkled appearance of weathered specimens have not been exposed. The umbo, in either valve, is small convex only at its apex where it may be slightly exogyroid, often more prominent in the left valve than in the right. The ligament surface of the left valve is tall-triangular, more or less deflected backward at its apex, with a gently concave ligament pit somewhat broader than either of the raised borders. The hinge of the right valve is shorter with an extremely shallow pit. The pallial line is distinct, quite close to the margin of the valves. Pallial pits and crenulations are visible in the neighbourhood of the ligament, but tend to disappear in full-grown specimens. The muscular scar is well marked, very elongate, transverse or only slightly oblique, posteriorly situated a little nearer to the inferior margin than to the hinge.

Dimensions.—The approximate dimensions of some left valves are :—

	Height.	Length.
1	40 mm.	46 mm.
2	34 mm.	37 mm.

There are no full-grown specimens with united valves; the immature specimens are not so broadly triangular as the full-grown ones. An immature specimen with united valves has a height of

27 mm., and a thickness of 15·5 mm. across both valves. Another specimen with united valves has a height of 28 mm., length of 26 mm., thickness of 11 mm.

Comparison with other species.—This species bears the closest resemblance to *O. Kalhora* and *O. Flemingi*, from both of which it is distinguished by its triangular shape and usually its somewhat more crowded foliaceous lamellæ. It also lacks the distinct radial ornamentation and the spines of *O. Kalhora.*

Occurrence.—This interesting fossil was discovered by Dr. Noetling in the last ammonite zone (with *Indoceras baluchistanense*, *Sphenodiscus ubaghsi*, etc.) of the Mari hills (zone 20 of the Des valley section, and in the equivalent zone 13 of the Mazar Drik section), in beds which may be regarded as belonging to the uppermost zone of the Maestrichtian [1].

OSTREA KALHORA [2] n. sp.

Pl. 19; Pl. 20, fig. 8.

Description.—Of medium size, usually fairly regular for an ostreid shell, orbicular to vertically oval, equilateral, inequivalve; exceptionally it may be elongate and deflected somewhat like an *Exogyra*. Umbo very small, scarcely projecting beyond the margin, with the embryonal portion strongly recurved backwards in exogyroid fashion. Cardinal margin sometimes straight and of moderate length, or else declivous on either side of the umbo. Up to a vertical measurement of about 20 to 24 mm., the shell has a flat, orbicular, fairly symmetrical, somewhat pecten-like shape, and is approximately equivalve. With increasing dimensions it rapidly assumes a shape analogous to that of many brachiopods, the pallial margin of the left valve becoming strongly arched along the umbonal-pallial axis from which the anterior and posterior regions of the valve slope steeply, the disposition being correspondingly inverted in the right valve, whose inferior region is apt to assume a tongue-shaped elongated outline. The outer surface of the left valve is ornamented with concentric lamellæ raised and frilled along their margins; they are distributed at intervals of about 3 or 4 mm., and are somewhat less pronounced in the umbonal region than in the zones of later growth. They are

[1] For a detailed account of the zonal constitution of the Upper Cretaceous of this region, see *Rec. G. S. I.*, vol. XXXVI, pp. 172-178.

[2] After the dynasty founded by the Baluch chief Yar Muhammad Kalhora. During the waning of the Mogul power, the Kalhora princes ruled Sind from 1701 to 1783.

crossed by radial tube-like ribs at intervals of 2 to 4 mm., generally much narrower than the intervening spaces, becoming especially pronounced at the periphery of each of the lamellæ, and thus contributing to their laciniated appearance. In the neighbourhood of the cardinal margin they have a tendency to increase in bulk and to assume the shape of spinose processes, somewhat like those of the recent *O. hyotis* Linn., which probably helped to anchor the shell which, otherwise, does not show any distinct indications of adherence. The ornamentation of the right valve is analogous, though the radial ribs are apt to be narrower and more delicate, and never show any tendency to develop into spinose processes as in the left valve.

The ligamental surface which is comparatively small and which has the shape of a depressed triangle, consists of the usual rather shallow groove with the shape of an approximately equilateral triangle, between raised flat margins. At its apex, corresponding with the embryonic portion of the shell, the groove is strongly recurved backwards in a hook-like exogyroid fashion, though this feature is not conspicuous owing to its small size. The pallial impression is almost marginal; there are no pits or punctations. The muscular scar is inferiorly situated, rather deep, elongate transverse or very slightly oblique, close to the inferior margin in a thoroughly posterior position, its posterior extremity being almost adjacent to the posterior margin.

Dimensions.—The following dimensions in millimetres were measured on the four figured specimens :—

Antero-postero diameter	44	44	43	40
Umbonal-pallial diameter	48	46	40	45
Thickness of united valves	22	24	23	26

Comparison with other species.—This species is related both to *Ostrea Morgani* and *O. Flemingi*, especially the latter, but is distinguished from both by its radial ornaments and spines. The shape also differs: *O. morgani* is triangular instead of orbicular or oval, while *O. Flemingi* is vertically more elongate and less terebratuloid.

Occurrence.—Upper Ranikot. It is the commonest molluscan in zone 3 at Jhirak (Vredenburg). It also occurs, generally of a smaller size, in zone 4 at Jhirak (Vredenburg K7,123) and north-east of Kotri (Vredenburg K10,608, 612).

OSTREA (FLEMINGOSTREA) FLEMINGI d'Archiac and Haime.

Pl. 20, figs. 1—7.

1854. *Ostrea Flemingi* d'Archiac and Haime, Descr. numm. Inde, P. 275, Pl. XXIII, figs. 14-15.

1916. *Liostrea Flemingi* d'A. and H.; H. Douvillé, *Pal. Ind.*, New Series, Vol. V, Memoir No. 3, p. 41.

Description.—Small, oval, with small pointed umbo, equivalve, convex, the left valve often more convex than the right and sometimes raised in a roof-like fashion along its inferior margin, in which case the junction of the valves exhibits a terebratuloid sinus.

Both valves are ornamented with wide-spaced foliaceous concentric lamellæ, the broad surfaces of which are quite smooth, or else frilled with scarcely perceptible radial folds best seen near the raised border of the lamellæ, especially of those nearest the umbo, and towards the margins of the shell. Except for those occasional and, in any case, very feeble radial markings, the surface of the broad lamellæ is normally quite smooth; the fine crowded concentric wrinkles intervening between the terminations of the main foliæ as shown in some of d'Archiac and Haime's illustrations are due to weathering and are apt to be developed more particularly in the right valve. The umbo is small, pointed, more or less exogyroid in its initial stages; it is either equally developed in both valves, or else that of the left valve projects furthest. The ligamental plate is small with the usual triangular, more or less exogyroid ligamental pit in the left valve; its entire surface is almost perfectly flat in the right valve. The pallial line is close to the margin and indistinct. The pits and crenulations are not clearly developed even in the neighbourhood of the hinge. The muscular scar is elongate-reniform, posteriorly situated nearer to the inferior margin than to the ligament.

Dimensions.—The following are the dimensions of four complete specimens :—

	Height	Length	Thickness across united valves.
1	30 mm.	23·5 mm.	16 mm.
2	31 ,,	24 ,,	14 ,,
3	31 ,,	24 ,,	17 ,,
4	31 ,,	25 ,,	19 ,,

Comparison with other species.—This species is very closely related to *O. Kalhora* from which it is distinguished by the feeble development or total absence of the radial ornamentation and

the absence of the characteristic spines near the cardinal area of the left valve. The middle eocene species is generally more vertically elongate and seldom exhibits so pronounced a terebratuloid sinus as is almost invariably observed in the Ranikot form. It is evidently a mutation of the Ranikot species, and it is noticeable that the specimens from zone 4 of the Ranikot are somewhat intermediate between *O. Flemingi* and the typical *O. Kalhora* of zone 3, though still possessing the characters of the latter sufficiently distinctly to be united with it specifically.

Occurrence.—D'Archiac and Haime's types were collected by Fleming in the nummulitic beds of the Salt Range in the strata overlying the coal-seam of Dandot, whose age probably corresponds with the Laki (Lybian) of Sind. The collections of the Geological Survey include specimens collected by Fleming, Theobald, Wynne and Noetling, without any precise details of their geological horizons. Those collected by Noetling are labelled as coming from Ara. No locality is mentioned for any of the other specimens. The same species was obtained by Mr. Hayden in the shales and sandstones (no. 16) overlying the Alveolina limestone of Tibet.

EXPLANATION OF PLATES.

PLATE 17.

Ostrea (*Flemingostrea*) *Morgani* n. sp.

Maestrichtian of the Des valley, zone 20.

FIG. 1 *a, b.* Left valve of an adult individual to show the broad triangular outline (anterior portion missing).

FIGS. 2 *a, b,* 3 *a, b.* Adult left valves showing terebratuloid sinus.

FIGS. 4 *a, b,* 5 *a, b.* Adult left valves showing the ligament groove.

FIG. 6 *a—c.* Specimen with the internal cast of the right valve on which is seen the impression of the muscular scar.

FIG. 7 *a—d.* Four views of a small specimen with both valves united.

PLATE 18.

Ostrea (*Flemingostrea*) *Morgani* n. sp.

FIGS. 1 to 6. Specimens from the Maestrichtian of the Des valley, zone 20.

FIG. 7. Specimen from the Maestrichtian of Mazar Drik, from the corresponding zone 13.

FIGS. 1 *a, b,* 2 *a, b,* 3 *a, b.* Specimens with valves united.

FIGS. 4 *a*, *b*, 5 *a*, *b*, *c*. Right valves showing internal characters.
FIG. 6 *a*—*c*. Specimen with inner cast of right valve showing impression of the muscular scar.
FIG. 7. Left valve with exceptionally wide-spaced concentric ornaments.

PLATE 19.

Ostrea (*Flemingostrea*) *Kalhora* n. sp.

FIGS. 1 to 4. Specimens from zone 3 (probably Lower Cuisian) of the Upper Ranikot, Jhirak. (See also Pl. 20, fig. 8.)
FIG. 5. Specimen from zone 4 (horizon of the "sables nummulitiques de Cuise") of the Upper Ranikot, north-west of Kotri.
FIGS. 1 *a*—*d*, 2 *a*—*c*. Specimens with united valves showing terebratuloid sinus.
FIGS. 3 *a*, *b*, 4 *a*, *b*. Specimens with united valves.
FIG. 5 *a*, *b*. Left valve showing internal characters.

PLATE 20.

Ostrea (*Flemingostrea*) *Flemingi* d'A. and H.

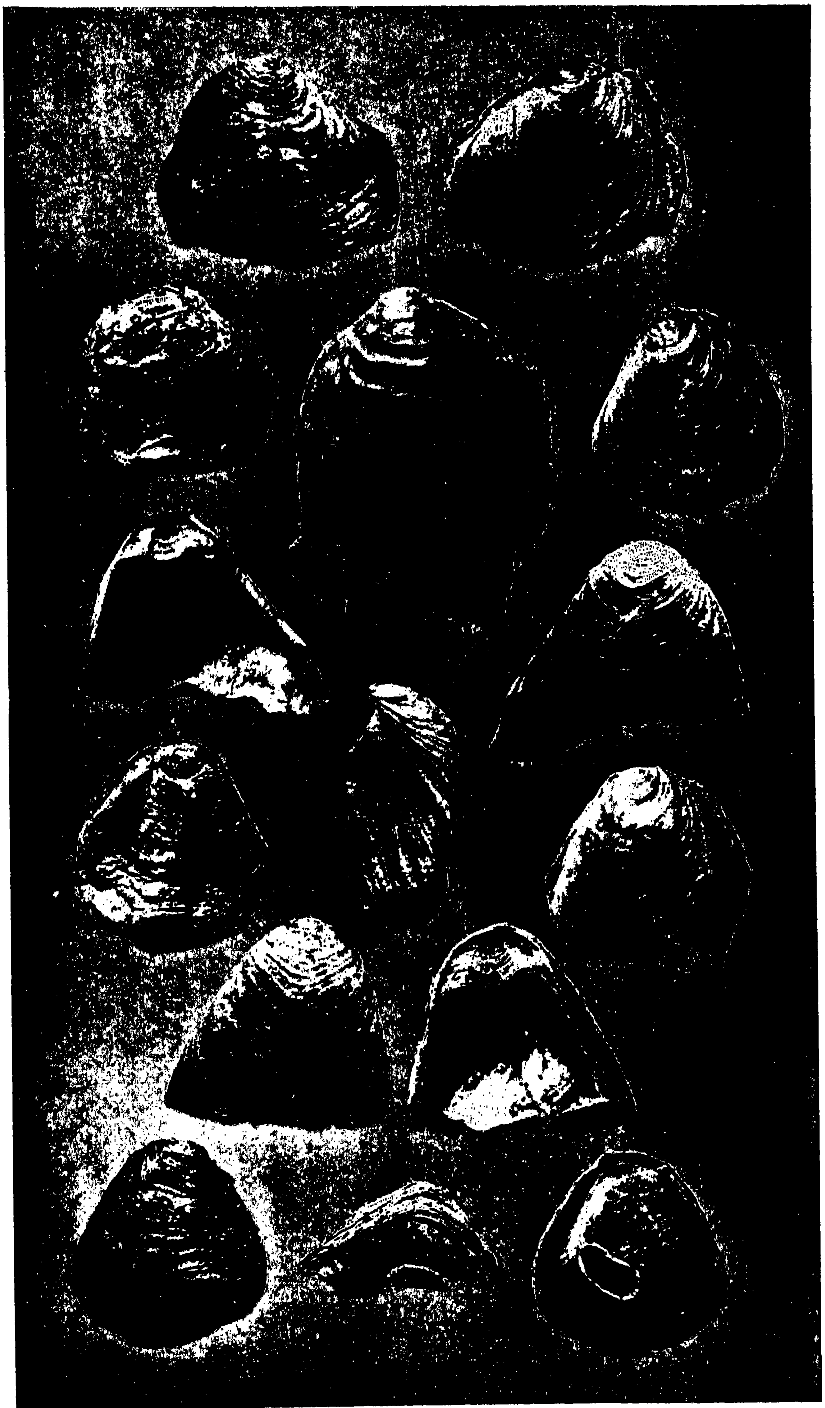
FIGS. 1 to 7. Specimens from the Middle Eocene of the Salt Range.
FIGS. 1 *a*—*e*, 2 *a*—*e*. Different aspects of specimens with united valves.
FIGS. 3 *a*—*c*, 4 *a*—*c*, 5 *a*, *b*, 6 *a*, *b*. Specimens with united valves.
FIG. 7 *a*, *b*. Left valve showing internal characters.

Ostrea (*Flemingostrea*) *Kalhora* n. sp.

Upper Ranikot. Zone 3, Jhirak.
FIG. 8 *a*—*c*. Specimen of the deflected-elongate race.

Photographs by E. Vredenburg. *G. S. I. Calcutta.*

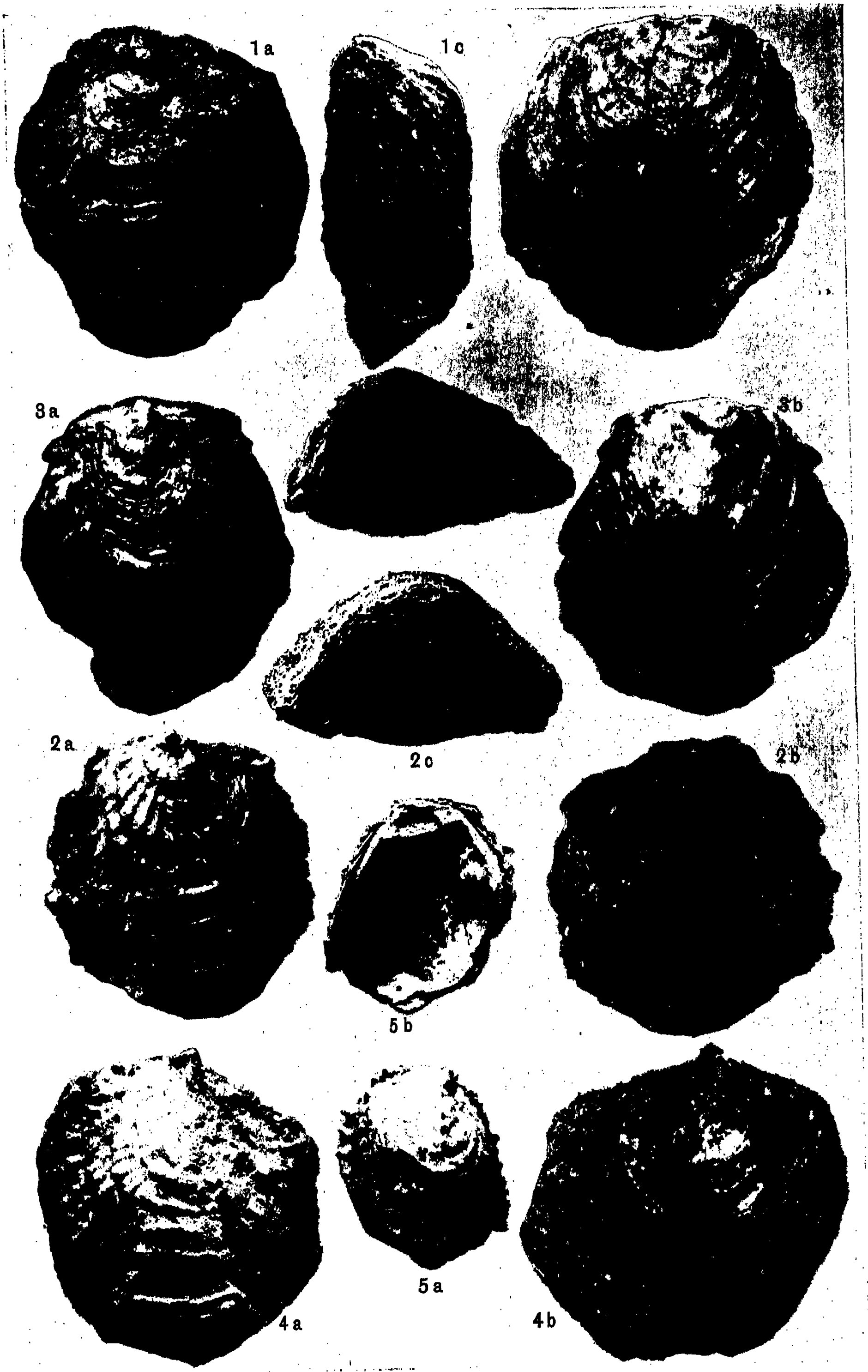
OSTREA (FLEMINGOSTREA) MORGANI, n. sp.



Photographs by E. Vredenburg. *G. S. I. Calcutta.*

OSTREA (FLEMINGOSTREA) MORGANI, n. sp.

Records, Vol. XLVII, Pl. 19.



Photographs by E. Vredenburg. *G. S. I. Calcutta.*

OSTREA (FLEMINGOSTREA) KALHORA, n. sp.

Photographs by E. Vredenburg. *G. S. I. Calcutta.*

Figs. 1-7 OSTREA (FLEMINGOSTREA) FLEMINGI, d'Archiac.

Fig. 8 OSTREA (FLEMINGOSTREA) KALHORA, n. sp.

RECORDS

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Part 4.] 1916. [December.

CONTRIBUTIONS TO THE GEOLOGY OF THE PROVINCE OF YÜNNAN IN WESTERN CHINA. 5. GEOLOGY OF PARTS OF THE SALWEEN AND MEKONG VALLEYS. BY J. COGGIN BROWN, M.SC., F.G.S., M.I.M.E., *Assistant Superintendent, Geological Survey of India.* (With Plates 21 to 28.)

LIST OF CONTENTS.

INTRODUCTION.

IN this paper I shall record geological observations made between Têng-yüeh (Lat. 25° 2′ : Long. 98° 33′ : Elevation 5,450 feet), and Ta-li Fu (Latitude 25° 42′ : Longitude 100° 12′ : Elevation 6,700 feet), the chief city and historic capital of Western Yünnan. These places are 170 miles apart on the main overland route between Burma and Western China, a road which is nearly always followed, and which has been described repeatedly by many travellers across Yünnan during the last 40 years. Leaving Têng-yüeh it proceeds in an easterly direction across the valley of the Shweli or Lung Chiang, and over the great Irrawaddy-Salween divide, through a pass at an elevation of over 8,000 feet. Thence it descends rapidly to the Salween or Lu Chiang, which it crosses at 2,200 feet and continues through the city of Yung-ch'ang Fu (Lat. 25° 7′ : Long. 99° 13′: Elevation 5,500 feet) to thegorge of the Mekong, or Lan-tsang Chiang. From this point a general north-easterly direction is followed, across the watersheds of the Yung-p'ing and Yang-pi Ho's, tributaries of the Mekong, until it reaches the high mountain wall of the T'sang Shan which borders the western shores of lake Erh Hai and rises to an elevation of 13,000 feet. No road crosses this range, and a wide detour is made leading through the gorge of the Hsia-Kuan Ho to Hsia-kuan, at the southern extremity of the Erh-hai, on the western shores of which, 10 miles further north, Ta-li Fu is situated.[1]

In 1880 this route was rapidly traversed by the Polish geologist von Loczy, whose work is referred to below. I was able to undertake two traverses to the north of the main route, the first across the Irrawaddy-Salween divide some 25 miles north of the point where the former crosses it, and the second from Yung-p'ing Hsien to Yun-lung Chou (Lat. 25° 48′ : Long. 99° 21′) and thence through previously unexplored country to Yang-pi, at the foot of the T'sang Shan.

The other journey which I shall describe here led me to the south of Têng-yüeh through Lung-ling (Lat. 24° 35′ : Long. 98° 44′ : Elevation 5,100 feet), and thence across the Salween to Shun-ning Fu (Lat. 24° 36′ : Long. 99° 57′, Elevation 5,800 feet). Leaving

[1] The map appended to this report finishes near the Yang-pi Ho ; the few miles between this river and Ta-li Fu will be shown on another map to be published with a later paper in this series.

this city I crossed the Mekong and, travelling north-east and north, eventually reached Hsia-kuan again. Only one or two Europeans have previously attempted this route and it was geologically unknown until my visit.

In the previous papers of this series I have given some idea of the difficult conditions under which the geologist is compelled to work in Yünnan, and in the areas with which I am concerned now, they were perhaps worse than elsewhere. Rapid marching with a mule caravan over some of the most mountainous country in the world, deluged with rain for the greater part of the summer, with inaccurate small-scale maps, or no map at all, is not conducive to minute geological accuracy. Opportunities for revisiting a complicated section never occurred, for in Yünnan, when the daily stage is commenced, it must be finished, or serious troubles arise in connection with the supply of food for man and beast. It is a land of immense distances, and as I had to cover these in the shortest possible time, it will be seen that my geological observations are of necessity first impressions. On the other hand, the usual absence of dense vegetation and soil, is a powerful aid which appeals forcibly to one accustomed to work in more tropical countries, and it is mainly owing to this circumstance that I am in a position to bring forward any results at all. I do not claim absolute accuracy for my notes or for my map, which are rather an attempt at broad generalizations and nothing more, but I believe they are not without interest in yielding some information about previously unknown or little known tracts in Western China, and further, they will be helpful to the future worker who, at any rate, will not be handicapped by a total lack of knowledge, when surveying the same parts of the province in more detail than has fallen to my lot.

Summary of Loczy's observations.

I give below a brief summary of Loczy's observations made during his journey along the route between Ta-li Fu and Têng-yüeh.

The T'sang Shan range is composed of gneissose granite, augen gneiss, phyllites, chlorite, mica and quartz schists which dip from 40°—45° towards the east on the Hsia-kuan side, but towards the west at Ho-chiang-pu. Between this place and Yang-pi, bluish, calcite-veined limestones and yellow sandstones dipping west were crossed, and on the geological map which accompanies the report of Szechenyi's

expedition are shown as belonging to the old Palæozoic limestone series.

100 metres above the level of the junction of the Hsia-kuan and Yang-pi Ho's, at Ho-chiang-pu, a high-level terrace was seen, which meets the bottom of the valley near Yang-pi. This valley is basin-shaped with gentle slopes, and is filled with lacustrine deposits of pebbles and clays in which lignite is found. Between Yang-pi and Yung-p'ing Hsien, that is to say for three marches past the villages of Tai-ping-pu and Huang-lien-pu, across the two ridges separated by the valley of the Shun-pi Ho, nothing but sandstones, clay schists, grits and an occasional limestone conglomerate was noted, usually with very disturbed bedding and even an induced schistose cleavage. Near Yang-pi the dip is north-westerly at 15°—20°, but close to Yung-p'ing Hsien a south-westerly dip prevails. While the strata about the former place belong to the Huronian-Cambrian Nan Shan sandstones, or are perhaps similar to the old Palæozoic flysch deposits, which were seen between Ta-chien-lu and Li-tang in Ssu-ch'uan, the rocks near Yung-p'ing Hsien bear more resemblance to the Mesozoic deposits of the provinces of S'su-chuan and Kuang-hsi. Leaving the Yung-p'ing valley, which is also filled in with lacustrine deposits, the two saddle-passes between it and the Mekong were crossed. The first looks down on Sha-yang which lies in a little basin, and the latter leads over a mountain into the narrow valley of the river itself. The whole region is made up of steeply folded sandstone beds and clay schists, which near the river dip north-east at 30°—35°. These are compared with the Palæozoic flysch mentioned above, but on the section traverse which accompanies Loczy's notes the area is occupied by Permo-Triassic rocks, whereas the map shows a band of the Wu-tai (Huronian-Cambrian) formation between Sha-yang and the Mekong.

On the right bank of the latter river at the bridge, unfossiliferous limestones alternate with sandstones and limestone conglomerates. Similar limestones were found as far as Shui-chai resting on diabase mandelsteins which occur with tuff beds and not in eruptive masses. At Ta-li-shao, a yellowish-grey, micaceous sandstone is interbedded with compact bands of bituminous limestone, from which badly-preserved specimens of the following fossils were obtained :—

Productus sp. indet. (*aff. latirostratus* Howse).

Spirifer cf. alatus Schloth.

From a grey sandstone a little further on badly-preserved specimens of the fossils named in the following list were obtained :—

Productus cf. *semireticulatus* Mart.
Spirifer aff. *bisulcatus* Low.
Entrochi, ampli et carinati.
Petraria sp. indet.
Pleurodictyum sp. indet.

These fossils according to Loczy are sufficient to prove the Carboniferous age of the strata in the vicinity of Ta-li-shao.

The road now climbs gradually to the pass which leads down to the Yung-ch'ang Fu plain, and along it the interbedded sandstones, dolomitic limestones and tuffs are brought into contact with masses of diabase porphyry. The Yung-ch'ang Fu plain is composed of lacustrine deposits. After leaving it to the south-west, weathered diabase porphyry underlies platey grey limestones, and dark grey bituminous limestones folded into a low syncline.

The lower limestone layers contain :—

Chonetes cf. *papillonacea* Phill.
Orthotetes (*Streptorhyncus*) *crenistria* Phill.
Rhodocrinus sp.

The upper bituminuous layers contain :—

Productus Yünnanensis sp.
Productus cf. *tumidus* Waag.
Productus elegans McCoy.
Orthotetes crenistria Phill.
Zaphrentis Beyrichi Roth.

These fossils are believed to indicate an Upper Carboniferous, if not a Permian age, for the rocks in which they are found.

Beyond Ta-shih-wo older unfossiliferous limestones occur, and on the descent to Pu-piao, plates of *Hemicosmites* and *Caryocrinus* were discovered in calcareous shales together with doubtful Silurian trilobite remains. The lower parts of the hills which surround the Pu-piao basin consist of diabase and olivine diabase with highly coloured shaly clays and tuffs.

The western side of the lacustrine basin of Pu-piao is built up of limestones and diabase tuffs dipping to the west. Above the latter near Fang-ma-chang, a shaly limestone was found which was largely made up of fragmentary fossils amongst which was a *Fenestella* related

to *F. Schumardi* Bront. These limestones are considered to be Carboniferous.

Loczy's journey across the Sålween valley was so hurried that no reliable observations were made and he admits theuncertainty of his descriptions of this most complicated region. At the head of the narrow rock-bound valley which leads down to the river, brecciated limestone bands were seen which are succeeded by diabase tuffs, brown calcite-veined sandstones and bands of calcareous marl. All these rocks are very disturbed and folded, yet in general they appear to be vertically bedded. Between them the diabase seems to be drawn through in veins. The strike of the series from north to south is clear, and the correlation of the diabases and tuffs with the Carboniferous appears probable. Many of the limestones are siliceous and enclose bits of dense siliceous tuff in great quantity. On its left bank the Salween is bounded by limestone. Crystalline schists were found on the Irrawaddy-Salween watershed though the range itself is largely built of gneissose granite. On the eastern slopes, shaly limestones and calcareous phyllites, with an easterly dip, alternate with one another. Quartzites, mica schists and phyllites seem to be folded into the gneissose granite. The Shweli valley is in gneiss, and at Kan-lan-chai there is a contact between gneissose biotite granite and the old crystalline schists.[1]

Notes on the Physical Geography.

The area described in this paper between Têng-yüeh and Ta-li Fu, a distance of only 115 miles as the crow flies, is furrowed by no less than three great river systems, the Shweli, a tributary of the Irrawaddy, the Salween and the Mekong, while the Yang-tze Chiang, and the head waters of the Red river of Tonking are found within distances of 40 miles on the north-east, and 15 miles to the south of Ta-li Fu respectively.

The Shweli.

Têng-yüeh itself is situated on a branch of the Ta-ping which enters the Irrawaddy near Bhamo in Burma, but within 12 miles measured on the map, though a much greater distance by road across the high granite plateau which lies between them, the Shweli is met with.

Even so close to its source it is a large stream with a strong current

[1] Die wissenschaftlichen Ergebnisse der Reise des Grafen Bela Szechenyi in Ost-Asien, Vienna, 1893. Vol. I, pp. 762-770.

flowing in a rocky bed some 50 yards wide, at an elevation of 4,200 feet where it is crossed by the main trade route. Looking up stream from the chain bridge suspended across the river, a well-marked series of high terraces can be observed both at the foot of the gentle slope on the west bank, and at that of the steeper one on the east. To the south of Kan-lan-chai as far as the Man-lu bridge, elevation 4,000 feet, which I crossed between Têng-yüeh and Lung-ling, the course of the river is directly south, and it is closely hemmed in on the east by the Irrawaddy-Salween divide from which it does not receive any important tributaries. Near Man-lu, it turns to the west, and soon afterwards assumes a general south-western direction, through the Chinese Shan States of Möng Yang or Hsiao-lung-ch'uan, and Mong Wan or Lung-ch'uan, until it reaches the frontier, along which it flows between Keng-yang and Nam-hkam in Burma. Its larger tributaries, the Nam Hkwan on the east bank and the Nam Wan on the west, flow parallel to the parent stream, that is to say in a south-western direction for some distance before joining it. I have already given an account of the upper waters of this river in an earlier paper.[1]

The Irrawaddy-Salween divide.

The great range of mountains which separates the catchment areas of the Irrawaddy and Salween, is the most marked geographical feature of Western Yünnan. Exactly how this immense mountain barrier arises between Eastern Tibet, Assam and Yünnan is not at present known, and it must suffice to state that to the far north of the area with which we are dealing, it seems that there are no higher ranges to the west of it. Further south, that is between Lats. 25° and 26°, it extends in a direct north and south line as an unbroken wall of peaks which attain altitudes of over 12,000 feet above the sea. But between Lats. 24° and 25°, the general elevation lessens and peaks of 8,000 or 9,000 feet are the rule. Just to the north of Lat. 24°, it is breached by the Salween, and still further south begins to lose its individuality, eventually disappearing into the complicated mountain system of the Eastern Burmese Shan States and the bordering trans-Salween districts of Yünnan. I crossed this range in three places, at Hsueh-shan-ting, elevation 11,000 feet, to the east of Kan-lan-chai, elevation 8,900 feet, and to the east of Lung-ling, elevation 6,800 feet. The exact positions of these places can be

[1] Contribution No. 1. The Bhamo-Têng-yüeh area. *Rec., Geol. Surv. Ind.*, Vol. XLIII, Pt. 3, 1913, p. 181.

seen at a glance on the map. The highest point in the range in this region is the Kao-liang-shan, which attains an elevation of nearly 12,000 feet about 10 miles to the north of Fêng-'kou, or Pass of the Winds, which leads the northern Têng-yüeh—Salween valley track across the mountains. From it I have taken the name Kao-liang Series for the group of ancient slates and phyllites which are infolded at the top of the range.

The Salween.

The large rivers of western and north-western Yünnan, the Shweli, Salween, Mekong and Yangtze Chiang are even more remarkable than the mountain ridges which separate them, and it is doubtful if any other part of the world can show such large streams flowing in the same direction so close together. As Colonel Sir Sidney Burrard has remarked, "The parallelism and proximity of the Yang-tze, the Mekong and the Salween in their exits from Tibet are amongst the most extraordinary features of the earth's land surface: each of these rivers drains a large area of eastern Tibet and on the surface of the plateau they flow at considerable distances from one another. But during their descent they bend to the east-south-east, and assume absolutely parallel courses, the Mekong in the centre being 28 miles from the Yang-tze and 20 miles from the Salween. Here there are three trunk rivers, each larger than the Sutlej, flowing through a mountain zone 48 miles wide."[1]

North of Lat. 24° 30′, the Salween receives no tributaries of any importance, for it is confined to a deep and narrow north and south running valley, bounded by high ranges which divide it from the Irrawaddy on the west and the Mekong on the east. Where it is crossed by the Têng-yüeh—Ta-li Fu route the bottom of the Salween valley is 2,000 feet lower than that of the Shweli and 1,700 feet lower than the level of the Mekong. The geological importance of these facts was first appreciated by La Touche who writes :—" It may be remarked that the Salween, throughout its whole course, flows through Palæozoic or Archæan rocks, and, unlike the Irrawaddy or the Himalayan rivers, it does not issue into a broad plain composed of Tertiary or Recent deposits, but maintains the deep, rocky, trough-like character of its valley to within a few miles of the sea-coast at Moulmein. It is much more effective, therefore, as a denuding agent than either the Irrawaddy or the Mekong, for these rivers lose their

[1] Burrard and Hayden. "A sketch of the Geography and Geology of the Himalaya Mountains and Tibet," Calcutta, 1907-08, p. 127.

power of eroding the rocks where they issue into the plains, that is, at a much greater distance higher up their course, relatively speaking, than in the case of the Salween. To this cause may be attributed the great depth of its valley as compared with those of the Mekong and the tributaries of the Irrawaddy, where these run parallel to it in Yünnan. .....These considerations lead to the conjecture that the Salween is of far greater age than either of the other rivers, and that the narrowness of its valley is due to the encroachment of these latter upon its original drainage area. It is perhaps only the great depth of the valley which has saved it from being diverted into one or other of the channels on either side of it."[1]

The bottom of the Salween valley where I crossed it on the Têng-yüeh—Yung-ch'ang Fu route is of a broad, one-sided shape, and the alluvial fans of numberless torrents running down from the divide, have formed a belt of gently sloping, though very low-lying ground, deeply dissected by the small, swiftly flowing streams themselves. This ground which is cultivated in places by the Shans, runs along the western side of the valley for about 20 miles and merges imperceptibly into the lower slopes of the divide. To the south it includes part of the territory of the Shan State of Möng-hkö, while to the north as far I could make out, the valley seemed to close in, and to become more like the Mekong gorge. In those regions it is inhabited by the savage Lisu tribes who have successfully resisted any attempt at exploration up to the present time. On the eastern bank of the river, that is the one corresponding to the steep side of the unequal V, quite different conditions prevail, and high limestone cliffs rise abruptly from the water, through which the torrents have cut narrow cañons for themselves instead of building out long alluvial cones.

The valley has a most unenviable reputation amongst the Yünnanese Chinese who quickly succumb if they stay for any length of time in it.

In spite of having no tributaries of any importance the summer rise of the Salween is enormous, as is clearly seen from the high water mark on the rocks which rise at its sides near the Lu-chiang bridge, where it is 120 yards wide, and from the great masses of the angular boulders with which its course is strewn. Not only is the river swollen by the melting of the snows in the highlands of Tibet, but it is flooded by torrential rains for hundreds of miles through its

[1] *Mem., Geol. Surv. Ind.*, Vol. XXXIX, Pt. 2, pp. 19-20.

Yünnan course and fed by innumerable torrents, insignificant enough in the dry weather, but which must convey immense volumes of water to the parent stream in the rains. The drenching rainfall that deluges the valley in the wet season, has given birth to the primeval jungle with which it is thickly clothed, for with the exception of the very summit of the divide where rhododendron scrub is found, the slopes are covered with dense tree growth which is not without a potent influence on geological structure.

Kingdon Ward's recent explorations have shown that the jungles of the Salween, give place abruptly to arid gorges above Lat. 28°, and that it is possible to pass in a day from a region where it rains practically every day for six months in the year, to a strip of country about 2 miles wide where the annual rainfall does not exceed 10 inches, and may be much less. The high, snow-clad peaks of the Irrawaddy-Salween divide check the rain-bearing winds from the south-west, and act as a rain screen to the valley further north. Any clouds which succeed in passing this barrier drop their moisture not in the Salween trough but on the peaks of the Mekong-Salween watershed, which from an average altitude of 15,000—17,000 feet about latitude 28° rise suddenly to peaks like K'a-gin-pu from 20,000 to 22,000 feet high. The Mekong-Salween divide in these regions acts as a second rain screen, and cuts off not only most of the rain from the Mekong valley but also to a great extent from the Mekong-Yang-tze divide. This effect is best seen on the latter range which instead of being clothed "with dense forests and waving meadows of alpine flowers, presents vast stretches of barren scree, towering pillars of naked limestone, grim rocky ridges, and an aspect so drear and bleakthat the scenery appals one."[1] The snow-line is said to stand at the unusually high elevation of almost 19,000 feet.

I also crossed the Salween near La-mêng, on the Lung-ling—Shih-tien route, but here the valley is considerably wider, though the same general features can still be made out.

The Mekong and its tributaries.

The valley of the Mekong is more like a true cañon than that of the Salween, from which it is separated by a high ridge. Kingdon Ward has shown that it too possesses an arid region which extends much further south than the corresponding one on the Salween, while the snow-line on the ridge which divides them is much lower

[1] F. Kingdon Ward, "The Land of the Blue Poppy," Cambridge, 1913, p. 262.

than 19,000 feet. The general character of the valley in the regions where I crossed it can be seen from the photographs which accompany this paper. As a rule, steep or inaccessible cliffs rise straight from the water, and there is no room for the accumulation of alluvial deposits in its bed. Occasionally a small torrent does succeed in pushing out a little delta into the parent river, but it is doubtful if these exist through a flood season. The asymmetrical shape of the Salween valley, which is a direct consequence of its heavier rainfall, though perfectly evident in the latitudes in which I crossed it, apparently becomes more accentuated further north, and has resulted in a natural cutting back of its eastern watershed against the Mekong. Ward's observations on the comparative volumes of the tributaries flowing to the two rivers makes this clear. Should the present peculiar conditions continue, the same writer's prediction of the final result will certainly come to pass and the Mekong will be captured by the Salween "at some point south of the arid region, beyond which this great difference of precipitation is not found (lat. 29°), especially as it [the Mekong] already flows at a very considerable elevation above that river."[1]

The Yung-ping, Shun-pi and Yang-pi Ho's are all affluents of the Mekong on its east bank, crossed between Yung-ch'ang Fu and Ta-li Fu, each of them flowing in rather deep valleys separated by high ranges from its neighbours. The valley of the Yang-pi Ho is divided from the lake basin of Erh Hai, on the shores of which the city of Ta-li Fu is built, by the lofty T'sang Shan range, which is breached near its southern termination by a tributary stream, the Hsia-kuan Ho.

List of Geological Formations.

The following rock groups were met with in the areas under description :—

Nan Tien Series . . .		Pliocene, Pleistocene and Recent.
Red Beds Series . . .		Upper Permian and Lower Trias.
Permo-Carboniferous . .		Devonian, Carboniferous and Permian.
Older Palæozoic Limestones .		
Pai-ma Beds and Shih-tien Shales		Silurian.
Pu-piao Series.	La-mêng Beds .	Ordovician.
	Shih-tien Beds.	
	Pu-piao Beds .	
Kao-liang System . . .		Cambrian and Pre-Cambrian.

[1] Kingdon Ward, *loc. cit.*, p. 257.

Gneisses and Granites of the Irrawaddy-Salween divide . .	Archæan.
Crystallines and Granites of the Shun-ning Fu area . .	
T'sang Shan Complex . .	

(The age of the granites associated with the crystalline rocks is not known definitely.)

Archæan.

The term Archæan is used by different writers on Asiatic geology in many different senses though invariably applied to metamorphic and crystalline rocks of great age. It is necessary therefore to define the exact meaning given to the term here, and I find that it suits the local conditions in western Yünnan best to follow the definition adopted by Bailey Willis for the provinces of Shan-si and Shan-tung:

"The term Archæan is applied to a basal mass of gneisses and schists, ...It is regarded as basal because it underlies all recognised groups and is separated from them by an unconformity of a most distinct and profound character; moreover, it is fundamental among rock masses known at the surface because it is itself apparently bottomless. Nothing distinct from it and older than it has yet been identified."

The structural and lithological characters of the western Yünnanese Archæan are exactly those of the Tai-shan complex of north-eastern China.

"The rocks are chiefly metamorphic schists and gneisses of indeterminate original character: associated with them is a large proportion of metamorphosed igneous rocks and a very small proportion of metamorphosed sediments; and the metamorphics are intruded by granites which are relatively young, though in large part probably pre-Cambrian. The structure of the gneisses and schists is exceedingly intricate; it is characterised by a universal schistosity; by a common banding; by complex shearing, thinning, thickening, plication and flow of bands; and such intricate arrangement of the very variable petrographic facies of the schists and gneisses as makes impossible any structural study by usual stratigraphic methods."[1]

[1] Research in China, Vol. I, Pt. 2, pp. 1-2.

Just as these lithological and structural peculiarities of the Tai Shan complex serve to distinguish it so unmistakeably from the oldest pre-Cambrian sediments of the Wu-t'ai system, so the Western Yünnanese Archæan is marked off from the younger Kao-liang system, even though the latter is itself intensely metamorphosed.

As it is impossible to determine the exact age of the intrusive granites associated with the crystalline rocks, although they are doubtless in many cases much younger, it is convenient to classify them altogether, and following this method they may be grouped as follows:—

The gneisses and intrusive granites of the Irrawaddy-Salween divide.

The crystallines and intrusive granite of the Shun-ning Fu area.

The T'sang Shan complex in the neighbourhood of Ta-li Fu.

Crystalline rocks of the frontier area and of the Irrawaddy-Salween divide.

The first of these groups is really the extreme eastern limit of that great band of crystalline rocks which stretches from the Burma-China frontier in the Bhamo area as far as the Salween, and extends north for unknown distances. I believe that it will prove to be a direct continuation of the Mogok gneiss of the Northern Shan States. Between Bhamo and Têng-yüeh the prevailing rock is a banded greyish-white gneiss of medium grain, composed of quartz, felspar and biotite. Garnet is the commonest accessory mineral and hornblende is usually absent. Variations in texture are often met with and the rock sometimes takes the form of a gneissose granite with large porphyritic, felspar crystals. Fine-grained amphibole schists with or without biotite and biotite and quartz schists are also found associated with it. Crystalline limestones of a pure white or grey tint, and saccharoidal texture also occur. The intrusive granite of the frontier regions is either a reddish-white, or white, fine-grained, rock made up of quartz, felspar and biotite. It forms either intrusive dykes or large batholithic masses such as the one in the immediate neighbourhood of Têng-yüeh.

In the higher parts of the Irrawaddy-Salween divide that I crossed, the commonest type of rock was a fine-grained, banded, black and white mica schist, though muscovite, quartz and hornblende schists also occur. The intrusive granite is a white variety with porphyritic felspars. Further to the south on the Têng-yüeh—

Yung-ch'ang Fu route, the lower western slopes of the divide are built of gneissose strata, but at higher elevations, fine-grained, biotite schists with thin alternations of quartz schist were found. Near the summit a gneissose granite occurs. Where the individuality of the great range commences to die down, that is still further to the south between Lung-ling and Chin-an-so, the granites are developed at the expense of the other crystalline rocks, which normally consist of fine-grained, biotite schists and white augen gneisses. Two varieties of granite were found, the first a coarse-grained kind which often showed indications of a gneissose structure, and the second, a finer form in thin veins, evidently of later age. The former was often pierced in all directions with thin quartz veins.

Crystalline rocks of the Shun-ning Fu area.

The crystalline rocks around Shun-ning Fu consist of granite, gneisses and schists; the latter obtain their greatest development in the immediate vicinity of the city, and extend for some 10 miles towards the north almost up to the Mekong. Both muscovite and biotite granites occur, though the former variety is by far the commoner. Mica schists and quartz schists with various kinds of gneisses build up the country between Shun-ning Fu and Yun Chou, some 20 miles to the south-east, but as this region lies beyond the area dealt with in this paper they need not be described here.

The T'sang Shan crystalline complex.

The T'sang Shan range is a high mountain wall which rises to elevations of 13,000 feet on the western shores of lake Erh Hai. Gneissose granite, gneisses and schists of various kinds make up the complex of which it is formed, but until the specimens which I collected have been examined, it is impossible to describe them in greater detail.

The Kao-liang System.

The Kao-liang system on the Irrawaddy-Salween divide.

Between the crystalline rocks of the Irrawaddy-Salween divide and the oldest, undoubted Palæozoic sediments there usually occurs a narrow band of phyllites, quartzites, slates and an occasional calcareous horizon, which I have already grouped together under the name of the Kao-liang system. There is always a marked unconformity between it and the underlying crystalline rocks: for example, crossing the main divide by the Têng-yüeh—

Yung-ch'ang Fu route, at the summit of the pass, the Archæan schists and gneisses suddenly give place to dark shining phyllites,[1] and there is no evidence to lead one to believe that a passage from the more metamorphosed and highly foliated series to the phyllites exists, the general impression being rather that the latter rest unconformably in a sharp synclinal fold of the former. Lower down the eastern slopes of the divide, silver-grey phyllites are interbedded with dark slates and bands of limestone. In the latter occurrence there is a marked difference from the Chaung Magyi system of the Northern Shan States, which otherwise they greatly resemble, for the former system does not contain lime in any form. The narrow bands found on the northern traverse across the divide broaden out further to the south, and near Lung-ling contain fine-grained, bluish and brownish, phyllitic slates with intercalated quartzites, while in the vicinity of Chin-an-so the ordinary lustrous grey phyllites traversed by numerous thin quartz veins are commoner.

The Kao-liang system of the Mekong region.

A band of rocks belonging to this system, at least 10 miles across, crops out just beyond the Mekong on the Yung-ch'ang Fu—Ta-li Fu route, rising to an elevation of 9,000 feet and forming the watershed between the great river and its tributary the Yung-ping Ho. Slates, talc schists, and bluish-white quartzites are the prevailing rock types. In a direct line towards the south this band broadens out and fills in most of the country between Shun-ning Fu and Yung-ch'ang Fu, while much of the area coloured as undifferentiated strata on my map, between Wan-tien and Ta-mung-tung, may possibly be made up of them. As a rule they form broken, deeply dissected country covered with forest, for the soils from them are poor and never seem able to support much cultivation. Owing to this jungle growth and a thick overburden of soil, exposures are poor and it is impossible to follow them very far. The peculiar way in which these rocks weather, partly as a result of their lithological composition, and partly owing to the excessive metamorphism which they have suffered having introduced a cleavage system that always shatters them, also makes geological observations a matter of great difficulty, for they quickly break up into innumerable, tiny fragments which decompose into a hard, tenacious clay on exposure.

[1] This outcrop is too small to be shown on the map.

Correlation of the Kao-liang System.

La Touche was impressed by the resemblance between the Chaung Magyi rocks and the Shillong series of the Khasia Hills in Assam though he does not agree with Sir Thomas Holland and E. Vredenburg who correlate the latter with the Dharwars of the Indian Peninsula. He rather inclines to the opinion that they correspond with the Hu-t'o system of Western Shan-si and as such should be regarded as pre-Cambrian. The presence of calcareous beds in the Kao-liang system makes a similar comparison in their case even more favourable, though it is probable that when examined in detail they will be found to contain beds corresponding both with the Wu-t'ai and the Hu-t'o systems in part, and perhaps even with the Cambrian.

The Pu-piao Series.

Under this term I group together the Ordovician beds of Western Yünnan, the name being taken from the type exposure near Pu-piao, a small town between the Salween and Yung-ch'ang Fu. From this locality Loczy had already described certain cystidean plates, as mentioned in an earlier paragraph.

Fossiliferous beds of this age were met with in three localities, Pu-piao, Shih-tien and La-mêng, and a considerable number of horizons are represented, though I had no opportunity to do any detailed work upon them. Yet they have yielded rich faunas which, described by Mr. Cowper Reed, have proved to be of considerable interest.

The Pu-piao beds.

In the type locality at Pu-piao the strata occupy a narrow band outcropping on the sides of the steep hill which rises to the north of the southern end of the Pu-piao plain. On the west they disappear below the metamorphosed Palæozoic limestones of unknown age which with the tuffs and lava flows and associated shales and limestones of Permo-Carboniferous age, build up that end of the valley, while on the east they are overlain by greyish, calcite-veined limestones of the same age. The rocks themselves consist of reddish-yellow, brownish-yellow and greyish-green, sandy shales or mudstones with bands of impure, hard, nodular limestone.

The following list of fossils has been supplied by Mr. Cowper Reed, the names of new species are marked with an asterisk. The majority of the fossils come from the mudstones:—

Didymograptus Murchisoni Beck.
Didymograptus Murchisoni var. *geminus* His.
Didymograptus indentus Hall.
Climacograptus cf. *Scharenbergi* Lapw.
Echinosphæra cf. *aurantium* Gyll.
Protocrinus ? sp.
Heliocrinus ? sp.
Echinoencrinus sp.
Caryocrinus cf. *turbo* Bather.
Pachydictya ? sp.
Orthis Pumpellyi Reed.*
Orthis (*Encyclodema* ?) sp.
Orthis sp.
Streptis sp.
Porambonites sp.
Ctenodonta aff. *medialis* Ulr.
Conocardium sp.
Raphistoma sp.
Conradella sp.
Hyolithes cf. *Clivei* Reed.
Hyolithes cf. *Loczyi* Reed.
Hyolithes sp.
Orthoceras sp.
Remopleurides aff. *latus* Olin.
Ogygites yunnanensis Reed.*
Illænus cf. *sinuatus* Holm.
Illænus cf. *tauricornis* Kut.
Nileus armadillo Dalm.
Nileus sp.
Bathyurus Mansuyi Reed.*
Lichas (*Metopolichas*) aff. *verrucosus* Eichw.
Calymene unicornis Reed.*
Phacops Martellii Reed.*
Primitia sp.

The most characteristic and abundant fossil from Pu-piao is *Ogygites yunnanensis ; Didymograptus Murchisoni* and its variety *geminus* appear to come next in abundance and *Orthis Pumpellyi*

seems to take the next place. Mr. Cowper Reed believes that this fauna undoubtedly points to a Lower Ordovician age, and Miss Elles considers that the graptolites are a typical assemblage from the zone of *Didymograptus Murchisoni*. The other organisms are allied to or comparable with members of the North European fauna of Ordovician times and scarcely any traces of an American element are apparent. The Pu-piao beds are therefore correlated with the Llandeilo beds of the British Isles.

The Shih-tien beds.

The Shih-tien beds which are perhaps a direct continuation of the Pu-piao beds to the south, though the intervening area has still to be surveyed, crop out on a hill side to the west of the alluvium-filled valley of Shih-tien. On the west they appear to be faulted against strata of Silurian age and on the east they disappear below the alluvium of the plain. For some miles to the south of the Shih-tien plain similar rocks are found, as can be seen from the map, and from their general lithological resemblance and on the strength of a few fragmentary fossil remains I correlate them with the Shih-tien beds. They are replaced further to the east by slates and mudstones of unknown age which I was unable to identify during the course of a single rapid journey across them. The Ordovician rocks of the Shih-tien hill consist of red, earthy limestones, massive, light grey, crushed limestones, greenish-grey limestones, greenish-yellow, hardened marls or calcareous mudstones, and dark, massive slates. The following list gives Mr. Cowper Reed's determinations of my fossil collections from Shih-tien :—

Sinocystis Loczyi Reed.*
Sinocystis yunnanensis Reed.*
Ovocystis Mansuyi Reed.*
Pyrocystis orientalis Reed.
Eucystis cf. *raripunctata* Ang.
Echinosphæra asiatica Reed.*
Echinosphæra sinensis Reed.*
Sphæronis lobiferus Reed.*
Sphæronis shihtienensis Reed.*
Heliocrinus fiscella Bather.
Heliocrinus qualus Bather.
Heliocrinus subovalis Reed.*
Heliocrinus cf. *balticus* Eichw.
Caryocistis bicompressa Reed.*

Camarocrinus asiaticus Reed.
Philhedra sinensis Reed.*
Hemipronites Giraldi Martelli.
Hemipronites sp.
Orthis Pumpellyi Reed.*
Rafinesquina ? sp.
Asaphus aff. *expansus* Linn.
Illænus cæcoides Reed.*
Illænus aff. *oblongatus* Ang.
Illænus aff. *Schmidti* Nieszk.
Illænus sp.
Lichas (*Metapolichas*) *celorhin* (Ang.) cf. var. *coniceps* H. V. Leucht.
Calymene sp.
Bellerophon (*Sinuites*) cf. *rugulosus* Koken.
Endoceras Wahlenbergi Foord.
Endoceras cf. *cancellatum* Eichw.
Endoceras aff. *Reinhardi* Boll.
Endoceras sp.
Orthoceras regulare Schl.
Orthoceras cf. *Kinnekullense* Foord.
Orthoceras cf. *scabridum* Ang.
Orthoceras (*Protocycloceras* ?) *Daviesi* Reed.*
Orthoceras sp.
Actinoceras cf. *Bigsbyi* Bronn.
Jovellania sp.
Cameroceras ? sp.
Cyrtoceras sp.
Spyroceras ? sp.
Trocholites yunnanensis Reed.*
Trocholites aff. *macromphalus* Eichw.
Planctoceras sp.
Tarphyceras sp.

Mr. Cowper Reed in his notes on the age and relations of these forms points out that they occur in at least four different kinds of rocks, which is quite correct. There appears to be no definite indication that the difference in age of these beds is great, and they all suggest the Lower Ordovician, especially stages B and C, the Orthoceras and Cystidean limestones of the Baltic provinces of Russia. Some American Trenton or Chazy affinities are also indicated and

at least one of the species has been recorded from the Ordovician of China. It seems probable that the Shih-tien beds are on a somewhat lower horizon than those occurring at Pu-piao which have yielded the *Didymograptus Murchisoni* fauna. Mr. Cowper Reed suggests that the Shih-tien calcareous beds which have yielded most of the cystideans are perhaps a lenticular patch of limestone in the midst of argillaceous beds, for it is noteworthy that the only other fauna with close affinities and some identical species, occurs likewise at Sedaw in the Northern Shan States, in an outcrop of beds not detected elsewhere as yet in that region, though all the evidence goes to prove that these Sedaw Beds belong to the same series as the Naung-kangyi Beds and to the lower division of the latter. This is a question which will only be settled by careful and detailed geological mapping, but I must say that my general impression gained during the few days I spent on the Shih-tien hills, is that the horizon is a definite and well-marked one. The Shih-tien beds appear to be represented at Lun-shan near the mouth of the Yang-tze and also in Shan-tung and Ssu-ch'uan.

The commonest fossils in the greenish limestones and greenish-yellow mudstones are the cystideans, especially *Sinocystis Loczyi* and *Ovocystis Mansuyi*, and of the cephalopods, *Orthoceras regulare.*

The La-mêng beds.

The La-mêng beds form a small outcrop faulted down into the Kao-liang rocks which are overlain on the east by the older Palæozoic metamorphosed limestones. The rocks themselves consist of hard, reddish or purple calcareous slates and mudstones resembling those of the Hwe Mawng beds in the Northern Shan States. The fossil collection from this locality is so poor and scanty that no satisfactory conclusions can be reached regarding its affinities. The fossils themselves are given below :—

Heliocrinus aff. *fiscella* Bather.
Crinoid or Cystidean stem joints.
Leptella ? sp.
Orthis ? sp.
Pachydictya ? sp.
Orthoceras ? sp.
Harpes aff. *Spasski* Eichw.
Ogygites ? sp.

These suggest a lower Ordovician age and there is probably little if any difference between the La-mêng and the Pu-piao beds.

Mr. Cowper Reed suggests from the occurrence of the cystidean comparable to a species found at Sedaw in the Northern Shan States (*Heliocrinus* aff. *fiscella*) that we have merely to deal with an argillaceous development of the Sedaw calcareous horizon, and therefore naturally with a somewhat different concomitant set of organisms owing to the varying enviromental conditions.

Looking at the palæontological results as a whole we find that there is a marked resemblance between the fossils from Western Yünnan, and the well-known Ordovician fauna from the Northern Shan States, as might well be expected from the geographical proximity of the areas. Several identical species occur, and the rich cystidean fauna from Shih-tien suggests the same horizon as that found at Sedaw. At the same time the general affinities of the fauna of the Naungkangyi and Hwe Mawng beds is not as close as might be expected. The rock from Pu-piao is not absolutely identical in lithological characters and no graptolites have been as yet found in Burma in the Naungkangyi beds. The fossiliferous beds cannot therefore be regarded as on precisely the same horizon, though both undoubtedly belong to the Lower Ordovician, and both have an European facies, and belong to the same division or series in South-East Asia.

The Ordovician faunas of Eastern Yünnan and Tongking seem to have a completely different faunistic type but the data are insufficient for a satisfactory comparison. The affinities of the Yünnan Ordovician faunas with those of the Central Himalayas are rather remote, but there is again present here a trace of the American elements as has been recently observed in more northern parts of China.

The Silurian System.

Beds of Silurian age were met with in two localities only, the first in close association with and probably faulted against the Ordovician beds on Shih-tien hill, and the second some miles further to the south, near Pai-ma, where their relations with the surrounding strata are not clear.[1] At Shih-tien the rocks containing the Silurian graptolites consist of black, fissile slates and tough, fine-grained greenish-grey or pinkish, flaggy slates, overlain by old Palæozoic limestones. According to Miss Elles the palæontological evidence shows that two horizons are represented, and the latter rock is the higher, belonging

[1] As it was impossible to map the Silurian beds separately during a rapid traverse, I have shown them with the Ordovician on my sketch map.

to the zone of *Monograptus Sedgwicki* (base of). From it the following species have been identified :—

Monograptus Sedgwicki Portl.
Monograptus lobiferus McCoy.
Monograptus tenuis Portl.
Monograptus leptotheca Lapw.
Monograptus atavus Jones.
Monograptus jaculum Lapw.
Monograptus concinnus Lapw.
Monograptus gemmatus Barr.
Glyptograptus serratus Elles and Wood.
Glyptograptus incertus Elles and Wood.
Climacograptus scalaris His.
Climacograptus Tornquisti Elles and Wood.
Gladiograptus perlatus Nich.
Mesograptus magnus Lapw.

The commonest form is *Monograptus lobiferus.*

The lower horizon of black carbonaceous and finely micaceous shales or slates contains abundant Climacograptids mostly preserved in scalariform view and therefore indeterminable, but some seem to be *Climacograptus rectangularis :* there is also a suggestion of *Mesograptus modestus.* Probably this bed is somewhere in the zone of *Orthoceras vesiculosus*, but it may be higher, at the base of the *Monograptus gregarius* zone. The assemblage is not perfectly convincing but the abundance of Diplograptids and the scarcity of *Monograptus* suggest this.

The species comprise the following :—

Monograptus incommodus Tornq.
Monograptus regularis Tornq.
Monograptus tenuis ? Portl.
Climacograptus rectangularis McCoy.
Climacograptus Tornquisti Elles and Wood.
Climacograptus sp.
Mesograptus modestus Lapw.

Older Palæozoic Limestones.

Distribution of the older Palæozoic limestones.

Narrow bands of older Palæozoic limestone were met with on each of the three traverses across the Salween valley, between Yung-ch'ang Fu and the Mekong, and between Shun-ning Fu and Yung-

ch'ang Fu. In addition to these I found two isolated outcrops near Kan-kou, and to the east of Ta-mung-tung on the Shih-tien—Shun-ning Fu road. The limestones form the actual bed and high bounding walls of the valleys of the Salween and Mekong between Têng-yüeh and Tali Fu, where in both instances they seem to overlie rocks of the Kao-liang system. The other smaller bands strike as a rule approximately north and south and are infolded with the Permo-Carboniferous beds. The map shows the Pu-piao series of Ordovician age to be in contact with them on the west, but this is not perfectly certain, and it is possible that a narrow band of Permo-Carboniferous tuffs and lava flows intervenes. Between Mung-you and You-tien on the Shun-ning Fu—Yung-ch'ang Fu road they form a narrow compressed syncline in the slates of the Kao-liang system, the centre of the trough being occupied by Permo-Carboniferous limestones.

Characters of the older Palæozoic limestones.

The limestones are unfossiliferous and the most striking feature about them is their universal brecciation, a character which is common to the Plateau Limestone of the Northern Shan States, to which a Devonian age has been attributed; indeed, La Touche has already pointed out that similar limestones exist in Yünnan. The maximum thickness of these rocks in Yünnan is unknown but it must be very great.

The prevailing type of rock is a light-coloured white or greyish-white dolomite, of a finely granular appearance. It is usually crushed and broken to an extraordinary degree, and fractured surfaces are traversed in all directions by minute cracks often filled in with secondary carbonates. On exposure these are dissolved away, and the surface of the rock becomes black, very rough and irregular. Further details of the structure of this formation are given later. Its homogeneity prevents any detailed classification and it resembles exactly the Plateau Limestone of the Northern Shan States in this respect. Concerning the latter La Touche has written:

"This paucity of organic remains, together with the rarity of outcrops of more than a few square yards in area, the homogeneity of the whole formation and the irregularity of the dislocations, whether folds or faults, that have affected the rocks, render any attempt to follow up definite horizons, or to establish any divisions within the formation, a hopeless task. And yet it bridges over a

period of continuous deposition of very considerable length, *viz.*, that extending from the close of the Silurian epoch, as shown by the graptolites of the Zebingyi beds, to the Productus and Fusulina limestones of Permo-Carboniferous age."[1]

Although outcrops are certainly more extensive and better exposed in Yünnan than in the Shan States, yet the total absence of organic remains in the former area militates most seriously against any attempt at sub-division.

The Permo-Carboniferous.

Distribution and characters of the Permo-Carboniferous.

The fossiliferous Permo-Carboniferous limestones and calcareous shales are always found in close association with the older, metamorphosed, Palæozoic limestones, which they unconformably over-lie. On the three traverses across the Salween valley, they occupy a good deal of the area, the limestones forming lower and more regular country than any of the older rocks. The older limestones tend to give rise to rugged hill tops covered with screes, or to vertical-sided cañons, whilst the Permo-Carboniferous limestones build more open valleys and form gentler hillsides through the soil on which their smooth isolated outcrops protrude. Of course there are many exceptions to this rule, but generally speaking it is possible so to roughly discriminate between. They are exposed in a broad band on both sides of the Yung-ch'ang Fu plain broken by a narrow zone of the older system. The commonest rock types are dark grey or bluish, massive limestones with a compact texture, which exhibit bits of shell fragments and foraminifera in thin section, whereas the older limestones only show recrystallised calcite and dolomite. The individual limestone bands are never very thick and are usually separated by calcareous shales, and rarely by more arenaceous deposits. From this system I have obtained large collections of corals, brachiopods, lamellibranchs, etc., but until these have been examined and described I do not propose to make any remarks about their exact age or affinities.

›revalent in Yünnan in the times
'mestones were deposited, and tuff
ɜ intercalated with thick ande-
and basaltic lava flows are com-

[1] La Touche, *Mem., Geol. Surv. Ind.*, Vol. XXXIX, Pt. 2, p. 195.

monly found amongst them, and indeed often make up the greater proportion of the rocks of the series. These igneous rocks are not shown separately on the map owing to its small scale.

The Red Beds Series.

Distribution and characters of the Red Beds Series.

The rocks of Upper Permian and perhaps Lower Trias age to which I have given the name Red Beds Series are only found east of the Mekong, between that river and the Yang-pi Ho, which roughly divides them from the crystalline massif of the T'sang Shan. They were met with on the main route between Yung-ch'ang Fu and Ta-li Fu, and they build the whole of the country between this route and the salt-producing districts around Yün-lung Chou further north. Their contacts with other groups are not normal ones, for in both directions, east and west, they are faulted against older rocks. In one doubtful case which occurs in the previously unexplored country between Kuan-ping and Yang-pi the underlying Permo-Carboniferous limestones crop out. In other parts of Yünnan I have noticed that a thick conglomerate usually separates the Red Beds from the Permo-Carboniferous limestones underneath, and seems to mark the position of a great unconformity for it rests on various horizons of the lower system. The Red Beds Series denotes a complete change in the orographical conditions of Yünnan towards the close of Permian times. A regression of the Permo-Carboniferous sea, perhaps indicated earlier by the prolonged outburst of volcanic activity in Western Yünnan, was followed by folding movements and the elevation and subsequent peneplanation of its deposits, which has resulted in the formation of this great arenaceous and argillaceous system, not unlike certain facies of the Gondwanas of the Indian Peninsula in lithological aspect. There is an almost complete absence of calcareous horizons in this series in Western Yünnan and the lower beds are characterised by thick deposits of gypsum and rock salt. Red and greyish-red sandstones, often in thick bands, and reddish, reddish-purple and greenish shales are the commonest rocks of the series, which forms a distinct type of country very different from that which results after the denudation of either the older limestones or the schistose strata.

The Nan Tien Series.

Under this term I group together all the Tertiary and Pleistocene deposits of Western Yünnan, the name itself being taken from the Nan Tien valley between Bhamo and Têng-yüeh, where they are developed on a very extensive scale. These deposits are entirely of lacustrine or fluvio-lacustrine origin, and as deposition is still in progress in some of the lake basins, it is often impossible to separate them from the more recent ones with which they are in continuous sequence. The geological changes that resulted in the formation of the lake basins have already been described in an earlier paper of this series,[1] and it is only necessary to point out, that the progressive capture of the lake basins by the streams which drain them, has resulted in the gradual lowering of their level, and in the uncovering of terraces along their ancient shores. These are always of detrital origin and formed from sands, sand-rock, clay or loosely compacted pebble-beds and conglomerates. Sometimes bands of lignite are found in the shales, which are also occasionally fossiliferous. The fauna which they carry is peculiar, and is very nearly related to living gastropod forms from the lakes themselves. The recent lake deposits are often partly formed from the older terraces washed down by torrents, which cut deep gullies through them, and distribute the debris across lower ground, as alluvial fans or steep sloping banks of denudation products. In the narrow river valleys which have not been the sites of former lakes, sands and gravels of recent origin are of common occurrence.

TRAVERSE No. I.

From Têng-yüeh to Yung-ch'ang Fu.

Têng-yüeh, elevation 5,450 feet, lies 60 miles east of Yung-ch'ang Fu, elevation 5,500 feet, on the main trade route between Burma and Western China. The geology of the country occupied in the first stage of 13 miles to Kan-lan-chai has been described in a previous paper, and it is only necessary to recall briefly how the road ascends a bare range of granite hills, which tower 2,000 feet above the

[1] Contribution No. 4. The Geology of the Country around Yünnan Fu, *Rec., Geol. Surv. Ind.*, Vol. XLIV, Pt. 2.

Têng-yüeh valley and attain a height of nearly 7,400 feet above sea level, and then descends to Kan-lan-chai, at 4,800 feet. From this place the next stage brings the traveller to the village of Ho-mo-shu, a distance of 13 miles. Commencing with a gradual descent across gneissose rocks, the Shweli or Lung Chiang, is crossed at 4,200 feet, after which the steep climb up the western slopes of the Irrawaddy-Salween divide commences. The river is about 50 yards across and flows with a rapid current over a rocky bottom composed of gneissose rocks. Its valley is wide and the ground on the western bank slopes away more gradually than that on the east. A series of high level terraces is well developed on both sides, and points to the recent uplifts which have affected the bed of the stream (see Plate 21). On the ascent no rocks are seen until $3\frac{1}{8}$ miles, when fine-grained biotite schists, with thin alternations of quartz schist, strike north-west—south-east and dip towards the north-east at 40°. There are outcrops of similar rocks right up to Ping-ho, but owing to the dense vegetation and thick soil they are not well seen. From this point to the top of the range at 9 miles, elevation 8,900 feet, a series of dark blue, shining phyllites with brownish bands crops out. Just beyond the summit and at the commencement of the descent on the other side, the phyllites are replaced by decomposed, gneissose granite into which the road has worn deep, while weathered banks of the rotten rock rise on both sides. It is fine-grained and contains abundant black mica. At 11 miles, where the road is level through pine forest, the granite, which is probably intrusive into true mica schists, is followed by phyllites again, and in the village of Hsiang-po-tzu, at 12 miles, elevation 6,800 feet, fine-grained, glistening, silver-grey varieties of this rock strike north and south and dip east at 40°. Towards Ho-mo-shu, 13 miles, elevation 5,400 feet, dark slates and bands of fine crystalline marble are interbedded with the phyllites.

The next stage leads across the Salween to the village of Ta-pan-chin, a distance of 11 miles.

From Ho-mo-shu there is a very steep descent for 2 miles, when the upper part of the talus slopes are reached across which the fall of the road is easier down to the river at $4\frac{1}{2}$ miles, elevation 2,200 feet. Poor exposures of decomposed reddish and brownish phyllites continue for $1\frac{1}{2}$ miles below the village, when they are replaced by greyish and bluish limestones, excessively brecciated and full of calcite infiltrations. The high cliff seen from Ho-mo-shu

towards the north and the cliffs which bound the northern side of the small tributary valley down which the road runs, appear to be composed of the same rock. The long alluvial and detritus fans brought down by side streams from the divide, hide the rocks after this, but their surfaces are covered with blocks of mica schist and they form a striking contrast to the opposite bank of the river, where cliffs of the old metamorphosed limestone seem to rise sheer from the water. The Salween valley is of an irregular V shape with the steep side on the east, there is a certain amount of cultivation on the surfaces of the alluvial fans where they are not deeply scored by torrents from the divide, and the narrow plain formed in this manner along the western bank of the river is part of the Shan State of Möng-hkö. The river itself is at least 120 yards wide at the point where it is crossed by the chain bridge. It is deep, swift and entirely confined in limestone, while the banks are covered with immense, angular blocks of rock which testify to the power of the stream during the rainy season. The cliff which is met immediately on crossing the bridge has been much undercut by the river. It consists of the brecciated variety of limestone and is stained red and brown. At its foot there are alluvial pebble beds which dip at low angles up stream.

The road now continues towards the south-east for 1½ miles and then gradually turns round towards the north-east, up the narrow valley of the tributary which flows down to the Salween from the Ta-pan-ch'in direction. Along the screes in the bottom of the main valley, exposures are poor, but the high wall which hems it in on the east, is capped by cliffs of the old metamorphosed limestones, and half a mile up the tributary ravine, just before the stream is crossed by a bridge which leads on to its left bank, similar rocks crop out. From the point where this stream debouches into the main valley, an isolated limestone hill can be seen towards the south. These small hillocks are common in the lower part of the Salween valley and similar ones were noticed during the southern traverse described in a later paragraph. A few fragments of a decomposed, igneous rock were found sticking out of the soil hereabouts, but it is impossible to say whether they belonged to a dyke or to an interbedded flow in the limestones, or are merely dislocated pieces brought down from the surrounding heights.

Occupying the 5 miles of the ascent between the last outcrops of metamorphosed limestone and Ta-pa-ch'in, elevation 4,500 feet,

there is a very varied succession of rocks, the general sequence of which is as follows :—

1. A thin band of decomposed amygdaloidal trap.
2. Hard, red shaly tuffs which grade into calcareous tuffs.
3. Three distinct limestone bands which strike north and south and dip west at 52°. The western band is the thickest and is easily distinguished by its perpendicular joint planes. These beds are close together and have formed well-marked ribs which stand out on the hillside for 200—300 feet above the road.
4. A thin series of reddish sandstone beds.
5. A thin limestone band.
6. Bands of doleritic and andesitic trap, some of which are dense and others amygdular with their cavities filled by zeolites, carnelian and calcite.
7. A thick bed of massive, greyish limestone which strikes north-north-east—south-south-west and dips at high angles towards the east; it forms the very narrow, cañon-like portion of the valley and contains brachiopods and lamellibranchs. Detached blocks of this fossiliferous limestone were found in the little side ravine in which the traps crop out.
8. Thicker bands of hard, bluish fossiliferous limestone with arenaceous layers. striking north and south and dipping east at 40°.
9. Calcareous shales with abundant remains of *Rhynchonella* and *Dielasma.*
10. Alternations of thin, shaly, greenish-grey tuffs and thin bands of hard brown sandstone.
11. 600—800 feet of grey Carboniferous limestone, vertical.
12. Shaly, green tuffs, well seen near the village of Liu-wun.
13. A thin band of bluish-white, calcite-veined limestone.
14. Old metamorphosed limestone.

The little valley which the road has been following broadens out considerably near Ta-pan-ch'in and the old metamorphosed limestones in which it is formed crop out in small detached blocks on the surrounding hill-sides, which rise some 400 to 500 feet above the village. Leaving the latter behind, there is another slight ascent for one mile until an elevation of 5,000 feet is attained, whence a

short descent leads to Fang-ma-ch'ang. A band of very decomposed trap appears to come between two beds of metamorphosed limestone, the second of which is followed by greenish and reddish shaly tuffs weathering down into sharp angular fragments, which just outside upper Fang-ma-ch'ang contain a decomposed diabasic lava flow. The weathering of this rock has proceeded to such an extent that nothing remains except soft material of dark reddish and grey shades with abundant partings and cracks of a lighter tint.

Beyond Fang-ma-ch'ang, where the road turns to the east, before proceeding to the south-east along the side of the Pu-piao plain, limestone bands occur which are full of small pieces of earthy tuff, and conformably following them, are rapid alternations of yellowish and greyish shales and tuffs. Outside lower Fang-ma-ch'ang, 3 miles from Ta-pan-ch'in, a platy, greyish-yellow limestone is interbedded with these. It is full of polyzoa, beautifully preserved on the weathered surfaces, crinoid stems and broken brachiopods, and is identical in appearance with the fossiliferous limestone of Mong-ta higher up the Salween valley.

The former locality was previously known as a result of Loczy's work. My own specimens from it have still to be described. Beyond it, more bands of decomposed trap were seen which soon gave place to massive, dark greyish-blue, calcite-veined limestones of the Carboniferous, cropping out along the hill-side over which the road winds for the next 5 miles before descending to the Pu-piao plain. In places corals were obtained from the limestones and dark nodules of chert also occur in them. Just before the plain is reached, a band of very decomposed diabasic trap occurs. The Pu-piao plain, elevation 4,500 feet, 15 miles from the Salween valley, is at least 9 miles long and about 1½ to 2 miles broad. It is covered with cultivation and contains many prosperous villages. The lacustrine deposits with which it is filled are in no way different from those of similar plains in various parts of the province, and do not need a separate description.

On the northern side of the valley, one mile from Pu-piao town, a hot spring issues from beneath a small limestone escarpment in two openings. The water is so hot that the hand cannot be kept in it and there is a strong smell of sulphuretted hydrogen in the vicinity. The limestone is grey in colour with numerous calcite-filled cracks and contains abundant crinoid stems. It is followed by

very decomposed and altered porphyrites and tuff beds, doubtless the same as those exposed on the opposite slopes of the valley.

A short traverse to the south led me to the tentative conclusion that a band of metamorphosed limestone comes between the Carboniferous strata on the west and the Ordovician rocks on the east of the valley respectively. The latter have already been dealt with in an earlier paragraph.

The top of the Pu-piao hill on the east is passed at 7 miles, elevation 7,000 feet, and a descent of 8 miles in a north-easterly direction leads to the Yung-ch'ang Fu plain, elevation 5,500 feet above the sea. The Carboniferous limestones which overlie the Pu-piao beds, crop out in small, angular masses of a greyish colour and are lenticular, nodular and banded with calcite. The fresh fractures are of a bright bluish-grey colour with sparkling facets of calcite and in them patches and veins of brownish-yellow dolomite are visible. They are followed by yellow sandy marls passing into soft yellowish sandstones containing casts of crinoid stems. These rocks are stained red and dark brown in places, but only poor exposures were obtained owing to the thick jungle growth. Continuing past Leng-shui-chai, they are followed by massive, grey limestones which crop out on the hill-sides in small cliffs. Beyond them, yellow sandy marls were seen intercalated with a few thin bands of nodular grey limestone, which reach to the top of the last steep descent to the Yung-ch'ang Fu plain. Opposite a point at 8 miles certain calcareous bands dip north-west at 20°. Just below the pass on the north there is a marsh surrounded by high limestone cliffs.

In the pass itself, a hard, grey, calcite-veined limestone overlies a darker material with bands of harder nodules, weathered into cliff-like escarpments on both sides of the small valley, and containing two caverns at the bottom on the north. From the lower of these a large stream issues. The limestone above the caves has a bituminous smell when fractured and contains both crinoids and corals. It strikes north 20° west, and dips towards the north-east at 15°. The whole formation, however, is bent into a small anticline for at the head of the little pass which opens on to the plain at Ta-shih-wo the dip is 20° north-west. The band of limestone at the top of the hill is 200 feet thick and of a coarser texture than the lower one which is 60 feet thick, and separated by shales and limestone bands, about 40 feet in thickness. The caves are in the lower band which is massive, slightly bituminous and fossiliferous. It also

contains more calcite than the other. Large collections of fossils were made here but they have not yet been described. The specimens collected by Loczy are listed in the paragraph dealing with his work. Just before the lacustrine deposits of the plain are reached, a band of decomposed porphyrite is crossed. The junction of the limestones with the igneous rock is well marked, both by the different character of the hill-side formed from the two formations, and by the soil of the latter being covered with cultivation, whereas the rocky limestone slopes have none at all.

The Yung-ch'ang Fu plain running from north to south is 20 miles long and 5 miles wide in the opposite direction. It has an elevation of 5,500 feet above the level of the sea. (See Plate 27.)

TRAVERSE No. 2.

From Yung-ch'ang Fu to Ta-li Fu.

Yung-ch'ang Fu lies at an elevation of 5,500 feet and is 105 miles from Ta-li Fu by the main trade route which this traverse follows.

The Yung-ch'ang Fu valley is filled in with lacustrine deposits of late Tertiary age which form the plain and consist of red and white clay beds, pebble beds and yellowish sands and sand rock. At the edges they form low rounded hills. After crossing the plain the road ascends gradually to the north-east up a bare hill-side, which becoming steeper for a short distance, proceeds up the valley of a small stream to the crest of the Salween-Mekong watershed at 11 miles, elevation over 8,000 feet.

The floor of older rocks on which the Tertiary deposits of the plain rest, is first seen near Lu-chia-chai, soon after the ascent commences where hard, bluish-grey, slaty limestones strike north-east—south-west and dip towards the south-east at 35°. Here I found a trilobite pygidium probably referable to the genus *Phillipsia*, encrinite stems and fragmentary brachiopod remains. The limestones are followed by shales with calcareous concretions containing crinoid stems, and then by thin beds of decomposed andesitic lavas as the steep part of the ascent is reached. Near the summit the old brecciated limestones crop out, with a vertical dip and a north and south strike; in appearance, and in direction of strike, they are quite different from the fossiliferous limestones that occur lower down

the hill. The width of country occupied by the older limestones is not more than 1¼ miles, when they are followed by more decomposed andesitic and diabasic lavas and tuffs, and, near the small village of Ta-li-shao, by fossiliferous calcareous shales and limestones. From these beds Loczy had already obtained the following fossils:—

Productus aff. *latirostratus* Howse.
Spirifer cf. *alatus* Schloth.
Productus cf. *semireticulatus* Martin.
Spirifer cf. *bisulcatus* Low.
Petraria sp. indet.
Pleurodyctium sp. indet.

I made a large collection of fossils including other brachiopods, lamellibranchs and polyzoa, which, it is hoped, will shortly be examined and described.

From the pass the road follows the side of a deeply-cut valley drained by a tributary of the Mekong, but towards Ta-li-shao it turns off towards the north before commencing the steep descent to the great river. Between Ta-li-shao and Shui-chai there is an abundant development of very decomposed contemporaneous lava and tuff beds. Shui-chai lies in a small, almost circular, basin-shaped hollow, with a flat bottom given up to rice and poppy cultivation and surrounded by steep, pine-clad slopes. It is 15 miles from Yung-ch'ang Fu. After leaving it, the road immediately commences the precipitous descent to the river, curving round to the north as it zigzags down the narrow cañon walls which rise sheer from the waters. These cliffs are composed of the old brecciated limestone and associated rocks. At the bottom of the gorge, elevation 3,900 feet, near the chain bridge which carries the road over the Mekong and beneath the great cliff of brecciated limestone covered with Chinese inscriptions on the western bank, reddish, shaly limestones were found. The river itself is from 80 to 100 yards in width with a very swift current. Great cliffs rise sheer from its side for nearly 2,000 feet and then slope away more gradually to still higher ground (Plate 22, lower figure). The cliffs on the eastern bank do not rise so high as those on the west but they are composed of the same rock. The bridge is 6 miles from Shui-chai, and after crossing it there is an exceedingly steep zigzagged ascent for 1½ miles, whence a descent of 1 mile leads to the village of Ta-wan-tzu. Near this place the track enters the valley of a small tributary full of alluvium, under which, here and there, poor exposures of slaty and

schistose rocks were noticed, identical in appearance with those of the Kao-liang system. They strike between north-west and south-east and north-north-west—south-south-east and they are usually vertical and very contorted. Gradually rising the road reaches Sha-yang at 10 miles, elevation 4,800 feet, the second stage in the journey to Ta-li Fu. The next stage of 13 miles leads in a general north-eastern direction to the Yung-p'ing Hsien plain. At first there is an ascent to 8,900 feet at 5 miles, at the top of a high ridge which divides the main stream of the Mekong from that of its tributary the Yung-p'ing Ho. The whole of the western slopes of this range and the steep and rocky descent for 3 miles on the eastern side, that is to a point one mile below the village of Hua-chiao, is made up of ancient, partly metamorphosed rocks, comprising slates, talc schists and hard bluish quartzites, with thin veinlets of quartz, on the ascent to the pass, and, on the descent, of broken outcrops of purple and white quartzites and slates. Exposures are scarce owing to subaërial decomposition of the rocks themselves and to the plentiful vegetation and the thick soil cap which covers them. From the pass, looking towards the east, a good view of the Yung-p'ing Ho valley is obtained, bounded by a moderately high and well-defined ridge, above which, in places, glimpses of the snow-capped heights of the T'sang Shan range near Ta-li Fu can be seen. Beyond Hua-chiao the formation changes and the older rocks are replaced by reddish shales interbedded with hard white sandstones. Near Tieh-ch'ang they are well exposed and are seen to form a very different type of country from the schistose or limestone rocks further west. Instead of the high, well-marked ridges of the former, or the steep cliffs and gorge-like valleys of the latter, low rounded hills now prevail, broken in places with small sandstone bluffs and usually covered with a thick cap of reddish soil. There is very little level ground. As the road descends to the Yung-p'ing Ho the alluvial deposits of the valley hide all outcrops. Near the bottom extensive pebble beds are found but they are replaced lower still by the recent alluvium brought down by the river, which flows in a flat plain upwards of a mile across. It is probable that the valley was filled in by a lake in late Tertiary times, and the lacustrine sands and clays, covered partially by alluvial fans washed from the hills which bound it on the east, continue some distance up the lower slopes over which the road rises to the next stage, the village of Sha-sung, a distance of

10 miles from the Yung-p'ing Hsien plain and 46 miles from Yung-ch'ang Fu. Rising in an east-north-easterly direction the road reaches the crest of the ridge which bounds the Yung-p'ing Hsien valley on the east, and separates its drainage from another tributary of the Mekong, the Shun-pi Ho, at Tien-chin-pu, 8,000 feet, 2 miles beyong Sha-sung-shao. At the commencement of the ascent red sandstones and shales strike a few degrees to the west of north and dip east at 28°. They weather very easily into heaps of tiny, angular fragments, which on continued exposure break down into a yellowish-brown or light reddish, clayey soil. Towards the summit hard bands of light red sandstone are interbedded with reddish and reddish-purple shales, which often contain small, irregular, greenish concretions.

A descent of 7 miles from the summit across purple and violet shales with frequent layers of white and yellowish-white sandstone and grit, leads to the crossing of one of the branches of the Shun-pi Ho, a mile beyond which lies the stage of Huang-lien-pu, elevation 5,100 feet, 10 miles from Sha-sung. At the crossing of the stream there are good exposures of hard red shales and shaly sandstones, which strike north-west—south-east, while the variation of the dip at this point and further back nearer Sha-sung indicates sharp folding. The Shun-pi Ho itself is crossed by a chain bridge, 4 miles beyond Huang-lien-pu, after which a long ascent to the north-east commences. The few visible exposures show the strata to be of the same general facies, that is, red shales with sandstone bands, but between T'ou-po-shao and T'ai-p'ing-p'u,[1] the shales become slaty and a general crushing and contortion is very marked. At first I was inclined to regard the purple slates of the T'ai-p'ing-p'u—Yang-pi area as older rocks belonging to the Kao-liang system, but after traversing them several times, I changed my mind, and now look upon them as representatives of the Red Beds Series, greatly metamorphosed owing to their proximity to the T'sang Shan which was elevated in later Tertiary times.

T'ai-p'ing-p'u is the sixth stage between Yung-ch'ang Fu and Ta-li Fu. It has an elevation of 7,300 feet and is 66 miles from the former place.

[1] These places are not shown on the map, but will be found on the one accompanying the next paper of this series which deals with the country between Ta-li Fu and Yünnan Fu.

Above the village the purple slates strike north 20° east and dip towards the west at 29°. Occasionally they contain greenish bands, while their joint planes are often marked with lenticles of quartz.

From T'ai-p'ing-p'u there is a gradual rise to the top of the ridge, separating the drainage of the Shun-pi Ho from that of the Yang-pi Ho, which is reached at 5 miles, elevation 8,400 feet. Identical rocks with the same strike continue, though a steeper dip to the west was measured. Above Ta-pin-li however the dip changes to 38° in an easterly direction. Around Ya-kou-tzu I found hard, greenish, speckled quartzites but they are quickly replaced by hard, contorted and well laminated purple shales which have an easterly dip as far as the pass. From here the road goes gradually down a long spur for 3 miles and then drops about 1,000 feet in the last mile to Yang-pi, the 7th stage of the journey situated at 10 miles from T'ai-p'ing-p'u, and at an elevation of 5,000 feet. A few poor exposures of the same types of rock were met with on the descent.

From Yang-pi the next stage leads to Ho-chiang-p'u, a distance of 12 miles. The road follows the direction of the Yang-pi Ho, that is to the south-east as far as P'ing-p'o at 10 miles. Here it makes a sharp turn to the east and enters the narrow gorge of the tributary stream, the Hsia-kuan Ho which breaks across the T'sang Shan range and carries the overflow from lake Erh Hai to the Yang-pi Ho, and thence to the Mekong. Both streams are only about 30 yards wide but have tremendous currents, though the valley of the latter occasionally broadens out into a narrow cultivated plain as at Ma-ch'ang and Sha-ko-tsun.

About a mile below Yang-pi, a cliff section shows hard, reddish sandstones with an east-north-east—west-south-west strike and a vertical dip, but after this, for the next 5 miles, the road traverses cultivated ground and no rocks are seen. The presence of the Red Beds Series is indicated however by the nature of the boulders and pebbles brought down by the tributary streams, by the shape of the hills and the colour of the soil. At 6 miles, close to Chin-niu-tou, these rocks end on the east bank of the river and the road becomes strewn with pieces of gneiss and mica schist, though to the east of the village I also found exposures of the old brecciated limestones. The river here flows in a deep and narrow valley, which towards the north is lined with a high terrace, on which the cultivated lands of Yang-pi and Ma-ch'ang are situated. As the

road proceeds through Chi-i-p'u and P'ing-p'o, and then turns east up the narrow gorge of the Hsia-kuan Ho, light-coloured mica schists were found cropping out at intervals, with a strike of north 30° east approximately. The main range with its terminal peak T'sang Shan, 13,000 feet, is built up of gneissose granite and mica schists.

From Ho-chiang-p'u a march of 10 miles in the same easterly direction leads to Hsia-kuan at the southern extremity of lake Erh Hai. The first exposures of the gneissose granite were obtained near the bridge which crosses the stream at Pe-t'a-chin, where the strike is approximately north and south, but just on the far side of the bridge several large pieces of dark, greyish-blue, calcite-veined, brecciated limestone were found followed by mica schists. I regard the limestone occurrences in this neighbourhood as the remnants of a former more extensive sheet, now only left in these small outliers.

Between the villages of Mai-tsao-shao and Shih-ch'ing-shao, 5 to 7 miles from Ho-ch'iang-p'u, the road does not follow the river bed as shown on the map, but crosses over a spur between two small tributaries. Here the dip of the schists is almost vertical and the strike north-west—south-east. The presence of rocks of the Red Beds Series, somewhere in the immediate vicinity to the south is proved by the colour of the silt-laden water of the eastern tributary, and by the numerous pebbles from them in its bed. A mile further on, the apparent dip measured from the beds on the opposite side of the gorge is 23° in an easterly direction. As the road continues, the gorge narrows in until at 9 miles the famous Hsia-kuan gate is reached, where it passes through an arch, and the narrow valley is constricted to a breadth of less than 50 yards, while the stream itself is forced into a course which cannot be more than 10 to 12 feet across, indeed a large fallen rock forms a natural bridge across the channel, which must be very deep and through which the river races with incredible speed and force (Plate 22, upper figure). Mica schists with the same dip and strike continue to Hsia-kuan, and it is needless to say that magnificent exposures of them are readily examined. The plain to the east and north-west of Hsia-kuan is of lacustrine origin and is extremely fertile.

A level paved road leads north from Hsia-kuan along the western shores of Erh-hai to Ta-li Fu, elevation 6,700 feet, a distance of 8 miles. The ground between the road and lake is of lacustrine origin and is intensely cultivated and full of villages, but that between the

lake and the lower slopes of the T'sang Shan is rough and broken and made up for the greater part of the alluvial fans of small tributaries from the high range, which have strewn boulders of white gneiss and mica schist over the surface.

Seldom has it been my lot to see a city amidst such beautiful surroundings as Ta-li Fu. Built beneath a high range, which towers above it for 7,000 feet, it is overshadowed by the great peaks which attain elevations of 14,000 feet above sea level, and which are snow-clad in the winter months. A mile away on the east, across the intervening plain carpeted with the living green of the Minchia peasants' crops, are the shores of the lake Erh-hai. This fine stretch of water is some 35 miles long and from 4 to 7 miles wide. It is navigated by small fishing and passenger junks and bounded in the distance by low red hills, a striking contrast to the high mountain wall on the west.

The edge of the lake is bordered with blocks of very metamorphosed, brecciated limestone and similar rock can be seen cropping out on the opposite shores. The lake basin is evidently confined to this formation, and seems to have originated in changes of level which have dammed back a pre-existing narrow valley, and have caused it to be filled up by the stream which once flowed through it.

TRAVERSE No. 3.

From Yung-p'ing Hsien to Yün-lung Chou and thence to Yang-pi.

The route followed by this traverse leaves Yung-p'ing Hsien and proceeds in a north-westerly direction up the valley of the Yung-p'ing Ho, and after leaving the watershed of this valley descends into that of the Lo-ma Ho, another tributary of the Mekong. The general direction of the track as far as Yün-lung Chou, 3 stages, 39 miles, is indeed parallel to the course of the main river and not far to the east of it. From Yün-lung Chou I marched north to Shih-men-ching and thence east to the valley of the Kuan-p'ing Ho, one of the upper branches of the Shun-pi Ho, and crossing previously unexplored country down the valley of this stream, eventually arrived at Yang-pi, on the main road between Yung-chiang Fu and Ta-li Fu.

The entire country is built of rocks belonging to the Permo-Triassic Red Beds Series.

The first march leads to Kuan-chiao, a distance of 10 miles, and, for the greater part of the way the road goes across the valley deposits, which consist of white and brownish-white, fine-grained shales, containing fragmentary plant remains and small, crushed gastropods and lamellibranchs. These shales undoubtedly prove the existence of a Tertiary lake basin in this valley. It is only when the road rises on to the lower eastern slopes of the hills above the stream that poor outcrops of shales and sandstones of the Red Beds Series are to be seen.

From Kuan-chiao a march of 15 miles leads to the second stage of Po-chiao. Just after leaving the former village there are exposures of greyish-red sandstones followed by red shales, and similar rocks continue for many miles, the shales predominating. They strike north 20° west and dip towards the south-west at 53°. It was very difficult to fix my position on the map in this region, the names of many of the villages which it shows are not known to the local inhabitants, nor does the road follow the main stream as delineated. I found that it turned in a northerly direction into one of the tributary valleys, ascended over a small spur and then continued up this side valley crossing the stream frequently. Innumerable blocks of red sandstone and masses of shale strew its bed, and steep, forest-clad slopes rise close to the water. In one place the stream flows through a narrow gorge and the track follows the eastern hill-side above it. The physiography of the region is very similar to those parts of Central Yünnan which are situated between C'hu-hsuing Fu and T'ing-yuan Hsien and which are sculptured out of the same strata. 5½ miles from Kuan-chiao a very steep ascent leads to the top of the ridge which divides the watersheds of the Yung-p'ing and Lo-ma Ho's. At eight miles the elevation is over 8,500 feet, from which altitude an extensive view of well-wooded country is obtained, the break in the hills where the Lo-ma Ho makes its way to the Mekong being particularly well-marked. A very steep descent from the crest leads down to a small tributary of the Lo-ma Ho, and after a slight ascent, an almost level path proceeds through the villages of Kan-hai-tzu and Hai-kou, whence there is a descent down a steep spur to Po-chiao, on the eastern bank of the main stream, 15 miles from Kuan-

chiao. Throughout the whole of this march typical red shales continue, striking a few degrees to the west of north.

From Po-chiao the road goes on in the same general direction to Yün-lung Chou, a distance of 14 miles. The river near Po-chiao is a deep and unfordable stream with a strong current in a bed from 50 to 100 yards wide, full of great sandstone boulders. In places the water practically fills the bed of the stream, but in others it is constricted to swift rapids, 15 to 20 yards across. The valley is narrow, very deep and precipitous, though sometimes there are narrow strips of cultivation on each side. The track follows the eastern bank, at times close to the water but often high above it. Sandstones and shales of the same general character are the only rocks met with. There is much folding and contortion, and on the west bank above Hsi-fang, a well-marked double, or S fold was seen, with its axis striking north 30° west. Further north the gorge narrows and it is only at the bends that small deposits of alluvium suitable for cultivation are found. These little fields are often covered with sandstone boulders which have fallen from the cliffs above. Few shale exposures were seen in this neighbourhood, and the country appears to be largely formed from a massive, greyish-red sandstone. Near Hsi-fang, grey grits and fine-grained, white sandstones crop out. After passing Sung-ma-tsin, a small Minchia village, the valley opens out a little, and the river is crossed by a wooden bridge in two sections, supported on a pier which is built on a large rock in the centre of the stream. On the western bank there are excellent outcrops of hard, reddish-grey sandstone bands, which one mile above the bridge dip towards the north-west at 19°, and near Yün-lung Chou at 38° to the north-west.

Six miles to the north of Yün-lung Chou and still in the valley of the Lo-ma Ho, lies Shih-men-ching, an important salt-producing centre. The river is crossed near the former town and 1½ miles further up it enters a narrow gorge where hard reddish sandstones of coarse texture and rough touch are found. The road does not follow the river bed but rises steeply past the village of Shan-ting-tzu and then drops down to its former level as it meets the stream once more. At this point, on the opposite bank, there is a hot spring much resorted to by the Chinese and Minchias as a bathing place. At the third mile, a small tributary from the east is crossed by a covered wooden bridge, and then the road enters the narrow gorge, ascending and descending and occasionally built up on a

causeway above the level of the river, which is not fordable. Near Shih-men-ching the red sandstones strike east and west and dip at 17° to the north. At this place I left the main valley and turned abruptly to the east up the narrow gorge of a small tributary in the bottom of which there are several brine wells, draining a salt-bearing horizon low down in the Red Beds Series.

The next stage is reached at Kuan-ping, 11 miles from Shih-men-ching, the road after leaving the latter place ascending along the north bank of the stream and passing through T'ien-erh-ching and Ta-ching, two large villages which possess important brine wells. In the month of March I found that the valley of the stream was practically dry and full of huge boulders. It is crossed by a bridge below T'ien-erh-ching. Rock exposures are poor and isolated owing to the violent denudation of the hill-sides, which has resulted in the formation of a great thickness of clayey soil, aided by the deforestation brought about by the demand for wood fuel in the local-brine-boiling industry. Such outcrops as were visible gave an east and west strike at first, but between T'ien-erh-ching and Ta-ching better sections showed a strike of 30° west of north and a dip of 34° in a north-easterly direction.

From Kuan-ping a route continues east to Têng-ch'uan Chou, a small walled city to the north of Tali Fu, but I left this and marched to the south-east down the valley of a stream flowing in that direction, in order that I might join the Yung-ch'ang Fu—Tali Fu route which lies to the south. This area has never been traversed by a European before and as I had no map, my geological notes are only suitable for general interpretation.

At Kuan-ping there are poor exposures of red sandstones and shales below the alluvium of the river bed, which is here about 50 yards wide. Three quarters of a mile below the village, red nodular shales strike north 20° west and dip south-west at 12°. The valley gradually widens as the road continues and at 9 miles, yellowish-green, finely laminated shales strike north-east—south-west. Sha-kia-tsun the next stage, a small village of S'su-chuannese colonists, is reached at 11½ miles. In the river bed at this place, hard, fine-grained, greyish sandstones with a yellowish, ferruginuous, cementing material, strike north 30° west and dip south-west at 40°. The village has an elevation of 6,600 feet and the next stage leads to Chi-ta-na, a distance of 13½ miles. 1½ miles from the former place, red sandstones dip to the east and constrict the stream in a narrow bed bounded

by steep wooded slopes. At $4\frac{1}{2}$ miles, a greyish-white, unfossiliferous limestone band crops out and is followed by fine-grained, red shales and then by bluish shales and reddish sandstones dipping and striking in the same direction ; I believe that it is a calcareous horizon in the Red Beds Series. In cutting through this band the river has formed a deep gorge to avoid which the road ascends over a spur between miles $4\frac{1}{2}$ and $5\frac{1}{4}$. At 6 miles the valley is left behind and an east-south-easterly direction is followed up the hillside which bounds it. Dark coloured or variegated, cleaved and splintered shales, with interbedded bands of hard quartzite are now found, and persist along the gradual ascent to 11 miles where an elevation of 9,000 feet was attained. On the descent to Chi-ta-na, white limestones crop out and on their weathered surfaces sections of brachiopods and lamellibranchs were seen, Chi-ta-na has an elevation of 7,800 feet and the next stage, the village of Tsun-wei, lies 17 miles to the south-east, the road ascending and descending over various small watersheds intersecting this area, the greater part of it being covered with thick pine forest. Exposures were poor and the only ones visible consisted of purple and greenish hardened shales or slates, intercalated with quartzites. These rocks seem to be metamorphosed representatives of the Red Beds Series. 4 miles to the east—south-east of Tsun-wei, which has an elevation of 7,000 feet, the route commences to descend into the valley of the Yang-pi Ho, and eventually joins the Ta-li Fu road just to the north of Yang-pi. In the intervening area purple slates and reddish sandstones were the only rocks seen.

TRAVERSE No. 4.

Across the Irrawaddy-Salween divide and the Salween Valley to Yung-ch'ang Fu.

Commencing from Têng-yüeh this route proceeds in a north-north-easterly direction to Chu-ch'ih, where it crosses the Shweli or Lung Chiang, thence it rises over the Irrawaddy-Salween divide and descends to the Salween or Lu Chiang valley in an easterly direction. From this point I marched in a south-easterly direction across unexplored country to Yung-ch'ang Fu. As I have already described the country between Têng-yüeh and the Shweli river, I shall take up the description of the geological features of this traverse,

from the village of Lin-chia-p'u which is situated on the lower western spurs of the divide a few miles above the river.

Lin-chia-p'u has an elevation of 7,600 feet above the sea, that is to say some 3,400 feet above the level of the Shweli, and the first stage leads in a general easterly direction across the divide to Ta-t'ang-tzu. Above the former village, muscovite schists, quartz and hornblende schists, strike north and south and dip towards the west at 42°. The road rises steadily to the pass at the top of the range across similar rocks, winding along the steep side of a narrow gully formed by a small, westerly-flowing tributary of the Shweli. Exposures are more frequent as the road gets higher, until near the top, continuous bare rock is met with. A small Chinese temple marks the crest at 11,100 feet and bears the expressive name, Hsueh-shan-ting or "snowy mountain top." A constant north and south strike was observed, but at the summit there is a dip of 25°—30° towards the east, indicating the presence of a compressed synclinal fold between this position and Lin-chia-p'u. The lithological character of the crystalline rocks is very constant and all the exposures consisted of a fine-grained, banded, black and white mica schist, which near the top of the range crumbles down into powdery outcrops, but at lower elevations weathers into large, jagged blocks with smooth joint planes. Narrow veins of a white, hornblende granite were found intruded into the mica schists in some places. A wonderful view is obtained from the crest: towards the east the eye wanders across the deep Salween valley to the Mekong divide and the mountain tops beyond that river,—snow-clad in the winter months; to the west across the Shweli to the distant hills of the Burma-China border country.

Descending on the eastern side of the great range, there is a very steep fall at first for ¼ mile, when a small tributary of the Salween is crossed at an elevation of 8,200 feet, thence there is a steep ascent to 9,000 feet, across a spur which leaves the divide between the peaks 11,440 and 11,610. About this point there is a considerable development of a white granite with large felspar crystals, but below the village of Chiu-kai, mica schists are again found striking north and south and similar in every respect to those already seen on the western side of the divide.

From Ta-t'ang-tzu the next stage led to Kan-ting-kai, situated a few miles up the Salween. A few hundred yards below the former village, hard bluish limestones full of calcite veins, with elongated,

yellow bands and lenticles, dip east at about 40°. I crossed over the Irrawaddy-Salween watershed on the 31st December 1907, and as the short winter day had finished before I completed the march to Ta-t'ang-tzu, I was compelled to traverse the last few miles in the dark and I am unable to locate exactly the boundary between the crystalline rocks and the limestones further down, so it is only approximately shown on the map. The limestones are followed by a series of yellowish slaty beds half metamorphosed into schists, soft and full of mica, foliated and highly contorted. Their strike is in the same general direction. Below their last outcrop broken and recemented limestones form a typical limestone breccia, which continues for a short distance and then disappears below the detrital deposits washed down from the steep sides of the divide by a torrent which drains the area around the Feng-kou peak. The road now enters the narrow valley of this stream which has carried down many mica schist and gneissose boulders and strewn them over its flood plain. On the south the bare sides of the valley are shut in by limestone cliffs, but on the north, outcrops of a very decomposed amygdaloidal trap were observed, which are presumably interbedded with the limestone. Near this point, the road, which up to the present has been proceeding in an easterly direction, turns towards the north, roughly parallel to the Salween which it follows for 5 or 6 miles.

Near the village of Mong-ta or Than-say, in the bed of a small tributary stream, I found outcrops of hard, greenish-grey, micaceous shales and sandstones, with interbedded grit bands, and in the stream itself, boulders of a fossiliferous crinoidal limestone with polyzoan remains and fragments of brachiopods. An examination of the ravine proved that the coarse crinoidal limestone, which is full of small, angular, shaly fragments, is intercalated in the shales, which strike north and south. The polyzoa appear to be closely allied to forms occurring in a similar rock at Fang-ma-ch'ang, 18 miles as the crow flies to the south-south-west, on the main Têng-yüeh—Tali Fu route, and, if so, they are probably of Permo-Carboniferous age. In the village itself, bands of a hard, blue limestone strike north and south and dip towards the west at 10°—12°.

After this the road winds over the grassy slopes of the lower spurs running down to the river or across the fields of rice and sugar-cane which occasionally cover them. Exposures are not

common, but outcrops of a metamorphosed and brecciated limestone were seen, which in appearance, structure and property of weathering down into a clayey red soil, greatly resembled the Plateau Limestone of the Northern Shan States. In addition to these, outcrops of a very decomposed, amygdaloidal trap were met with. The fossiliferous limestones and interbedded traps seem to lie in a syncline in the older metamorphosed limestone which forms the high cliffs on the east bank of the Salween opposite Kan-ting-kai. This place has an elevation of 2,900 feet above the sea.

I crossed the Salween a few miles below Kan-ting-kai by ferry and then struck out in an east-south-easterly direction, across previously unexplored country, arriving 5 days later at the northern end of the Yung-ch'ang Fu plain. Owing to the unsurveyed and mountainous nature of this area, I found it a matter of extreme difficulty to fix my exact position, and consequently my geological map of this particular area is of the sketchiest character. The greater part of the country is undoubtedly occupied by limestones of the same age as those found on the descent to the west bank of the Salween, and my impression is that they occur in closely-packed, isoclinal folds, which have an approximately north and south strike. Half way across to Yung-ch'ang Fu, the ground is covered with small, sharp outcrops of pale and dark grey, brecciated and unfossiliferous limestones, which near the Lolo villages of Myin-ka and Ho-wun contain bands of a very decomposed andesitic lava associated with weathered, greenish shales. In the valley of a small stream near the latter place, I noticed boulders of the dark fossiliferous Permo-Carboniferous limestones containing crinoid stems and sections of *Euomphalus* sp. This is sufficient to prove that these beds crop out somewhere in the vicinity, though I was unable to discover them owing to the thick covering of the usual red soil. Further to the east, near the Lolo village of Sow-wa-shu, a bluish, banded limestone strikes north 10° west, with a vertical dip, and contains crinoid stems and corals, among which the genera *Zaphrentis* and *Cyathophyllum* appear to be represented. It is followed by the brecciated limestones which in their turn are replaced by platy, reddish limestones weathered down into soft yellowish marls, and followed by very contorted shaly limestones. Near the village of Sha-ho-ch'ang, soft, reddish, marly sandstones are found with a vertical dip and a strike of north 30° east. These rocks are pierced by basaltic dykes. Between this place and the

northern extremity of the Yung-ch'ang Fu plain, I found hard, greenish shales, striking north 30° west, and dipping at high angles towards the east, followed by clay schists and phyllites, striking in the same direction, but possessing a lower dip.

TRAVERSE No. 5.

From Lung-ling to the Shih-tien plain.

These two places lie 50 miles apart on a route which runs in a general east-north-easterly direction across the southern extension of the Irrawaddy-Salween divide and the Salween valley. It furnishes a good series of rock exposures similar to those met with on the Têng-yüeh—Yung-ch'ang Fu traverse, some 20 to 30 miles further north.

From Lung-ling, at an elevation of 5,100 feet, the road runs towards the north-east and for about 2 miles crosses the paddy fields, which cover the alluvial and lacustrine deposits of the plain, and then ascends a small tributary valley. At the commencement, fine-grained bluish and brownish-white banded mica schists alternate with hard white and brown speckled quartzites which strike north 30° east and dip towards the north-west at 35°. At first the quartzite bands are thick and form the greater part of the exposures, but as the road ascends they gradually become thinner until near Ssu-tzu-po they completely die out. Beyond this point very fine-grained schists and phyllites are found in poor and decomposed exposures. I believe that these rocks are of the same age as the phyllites folded into the crystalline rocks of the divide further to the north between Kan-lan-chai and Ho-mo-shu. An elevation of about 6,600 feet is attained at the fourth mile whence there is a short, steep descent to a small stream near which I found a fine-grained, white granite *in situ*. This granite continues across the minor undulations to the small rice plain of Tuan-chia-chai which is about 8 miles from Lung-ling and has an elevation of 6,300 feet. The quartz veins in the granite give rise to numerous pebbles and boulders with which the surface of the soil is strewn. Although usually of medium grain there are finer and coarser bands of granite; in the latter the felspars are developed in large perfect crystals and the rock seems to have some indications of a gneissose structure. One mile above Tuan-chia-chai I saw blocks of the fine-

grained mica schist again but not *in situ*, which seems to indicate that the granite is intrusive into these rocks. The hill tops form small isolated, rounded knolls covered with ferns and long grass, resembling very much the granite country in the neighbourhood of Têng-yüeh (see Plate 25, lower figure). From Tuan-chia-chai the next stage leads in a north-easterly direction to the village of Herh-tou-ching. On the slopes above the former place thick soil beds are seen full of quartz pebbles of varying sizes and tints. At first there is a slight descent to the Ching-an Ho, a tributary of the Shweli, and about ½ mile from the valley the hot springs of Huang-tsao-pa are passed. Here a copious supply of hot water bubbles out of the ground, just below a small bluff of rather fine-grained biotite mica schists containing abundant, small felspar crystals. There is a strong smell of hydrogen sulphide in the immediate vicinity, but the water appears to be unusually pure as there are no deposits from it. The road now ascends up the left bank of a stream tributary to the Ching-an Ho, which drains the south-easterly extension of the very much diminished Irrawaddy-Salween divide. For the first 3 miles up this valley there are practically no exposures as the detritus of the stream and the cultivation of its alluvial patches mask all the rocks, but near the road numbers of quartz boulders are strewn about. After this the track is worn deep into soft outcrops of decomposed gneiss, and at 4 miles coarse gneissose granite is seen with its foliation planes striking north 20° east. A similar rock continues until a few hundred yards below the top of the range, which is reached at 5½ miles, elevation 6,800 feet, when a true biotite granite replaces it. It is followed a short distance down the other side by white augen gneisses, separated by thin bands of biotite schist which have a vertical dip and strike north 32° west. The exposure is a small one and is soon followed by coarse-grained gneissose granite which at 6 miles gives place to the fine-grained intrusive granite once more, weathering out in large rounded masses. The Chin-an-so plain at 6½ miles has an elevation of 6,600 feet, is 4 miles long and ¾ mile broad. At the southern end there is an alluvial terrace, about 100 feet above the present river level. Most of the smaller villages of the plain are built on this terrace, which gradually decreases in height down stream, that is to the north. At the present time the river is actively deepening its bed. Leaving the plain there is a steep ascent in an easterly direction for 2 miles when an

elevation of 7,700 feet is attained at 8 miles, the commonest type of rock found on the way up being a hard, lustrous, silver-grey phyllite, which weathers down into small, multicoloured fragments of red, brown and bluish shades. Thin quartz veins are quite common in this rock. The strike is north 25° west and the dip usually high, but in places it flattens out and low anticlinal folds are then visible. The road continues along the top of the bare ridge on which poor exposures of the same type of strata were obtained. The stupendous gorge of the Salween is first seen down the narrow valley of an easterly flowing tributary, but just before this, looking towards the north a fine view of the divide, with a glimpse of the Möng-hkö plains at its foot, was obtained. At this point, hard greenish slates crop out, and interbedded with them I noticed two bands of hard, bluish-grey, slaty limestone less than 10 feet in thickness, followed by decomposed reddish phyllites which reach down to Herh-tou-ching. The most remarkable feature in this march is the diminution in height, or flattening out, of the Salween-Irrawaddy divide in this region. The breadth of country occupied by the rocks of the Kao-liang series points to a widening of the folds into which they are thrown, and consequently a weakening of the compressive forces by which they were crumpled into such narrow bands further up the divide.

From Herh-tou-ching the next stage leads across the Salween itself, a distance of 9 miles in a general easterly direction. After continuing along the same ridge for ½ mile a descent to the river begins, the road dropping from 7,500 feet to 2,100 feet at the ferry. At first winding easily down the side of a pine-clad slope, only poor exposures are obtained, but these are seen to consist of the same kinds of rock: soft, reddish, decomposed phyllites, pale green slates, often traversed by thin quartz veins and hard quartzites. At 2¾ miles I met with hard, angular-fracturing, purple slates outcropping on the roadside 100 feet above the little stream which rushes down into the small La-mêng plain. These are fossiliferous and have yielded remains of trilobites, cystideans and brachiopods which are the same as those obtained from Pu-piao, and have enabled the Ordovician age of the rocks themselves to be fixed definitely. The older slates of the Kao-liang series strike north 25°—30° west and dip to the south-west at 35°-40°, while the Ordovician beds appear to strike west 30° north and to dip in a north-easterly direction at 50°. The actual junction of the two series was not seen,

but there is considerable disturbance of the strata and some indication of a fault between them. The thick soil-cap which covers everything in the next $\frac{1}{4}$ mile down to the hamlet of La-mêng is strewn with a variety of pebbles and boulders of phyllite, quartzite and purple slate, evidently from the Kao-liang series. In the village itself, which is surrounded by a little alluvial plain, hard, grey, metamorphosed limestones of the older Palæozoic crop out and the steps which carry the road from the upper to the lower part of the village are cut into this formation The alluvial plain fills a tiny basin-shaped depression surrounded on all sides by the smooth tops of pine-clad hills. It is a kind of hanging valley, for immediately outside the village, the eye meets the deep gorge of the Salween. The cliffs on the opposite side are bare, except for a few straggling pines, and from this point they appear to rise to heights of 3,000 or 4,000 feet. The small tributary valleys are like the one in which La-mêng is situated, that is to say, they are of a broad, open V shape at the top, in which small villages can be seen dotted here and there, with very steeply graded falls, shallowing down to narrow outlets before they reach the parent stream. On each side the view is confined by high bounding ridges while the divide can be seen extending to the far north, its snow-topped peaks terminating in a bank of clouds on the horizon. Immediately in front and obstructing the view of the valley to the east and north-east are three, long, rounded hills which appear to rise straight from the narrow part (Plate 24, lower figure). Further north another one can be seen rising from the Möng-hkö plains. They are covered with bright Indian-red soil, patched with hill cultivation or clumps of pine scrub, while at intervals, exposures of the old metamorphosed limestone protrude through the surface. After turning to the north-east, the road makes a detour to the south-east down the side of a ravine and then zigzags along the spurs in full view of the river. For the first $1\frac{1}{2}$ miles below Lamêng the old metamorphosed limestones are found, when they are replaced by a vertical band of red sandstone which strikes north 35°—40° west, and is followed by a thin layer of limestone breccia, and then by another 300—400 feet of the ancient, brecciated limestone. Below this a thick band of decomposed, igneous rock occurs, followed at once by the laminated, light grey limestones of the Carboniferous. These are not metamorphosed in the slightest degree and are fossiliferous, as they show sections of brachiopods on their

flat, weathered surfaces. They strike north and south and dip at 85° to the east. Further down still, at a place about 300 feet above the river, a platy, dark greyish-blue band shows impressions of bivalves, a specimen of which I collected but which has not been determined yet.

At the ferry the river flows between almost perpendicular limestone cliffs rising sheer out of the water for 600—700 feet. The river itself is about 100 yards across, and at this point the current is slow and the depth very great. It is noteworthy that the small tributary streams come down in the rainy season with a force sufficiently strong to wash small deltas out into the main river, which, large as it is, is not powerful enough to remove them quickly. These are not deltas in the true sense of the word as they are formed for the greater part of immense angular masses of limestone, doubtless produced during the landslips which score the sides of the upper parts of the tributary valleys. The flood level of the river was clearly visible at least 50 feet above its winter one. Leaving the ferry the route runs at first southwards, and then turns to the east, ascending almost 1,000 feet in a mile, after which it continues to rise more easily to Tai-ping-tzu, reached at mile 2 from the ferry, at an elevation of 4,000 feet. Over the first ¼ mile of road, the Carboniferous limestones crop out, to be followed by a decomposed, basic, igneous rock of a greenish colour, which is well displayed in the bed of the rivulet flowing through the village, in very cracked and jointed outcrops with superficial brownish and reddish tints.

From Tai-p'ing-tzu the next stage leads the road in an easterly direction to the village of Wan-chia-tien. From the first place there is a steady climb of about 1½ miles up the steep ridge behind the village. For about ½ mile the decomposed, basic lava crops out in sections that are identical with those seen lower down, but at that point where the road takes a sharp turn to the north, limestone breccia, consisting of broken and recemented, angular fragments of limestone formed into a hard rock, comes in, and is soon followed by exposures of the typical, metamorphosed limestone weathered in the peculiar manner of this rock, so that each broken particle is clearly defined. Continuing over outcrops of similar rock the road reaches an elevation of 5,200 feet at Ma-i-shui where reddish, shaly tuffs, breaking down into irregular fragments under the action of the weather, are found striking north 35° west

and dipping north-east at 65°. From here there is an extensive view of the Salween flowing through the low Möng-hkö plains, backed by the high wall of the great divide. At 3¾ miles the road reaches the southern side of a ridge overlooking a deep valley, along which thick bands of greenish tuffs, with the same strike as the red ones, are crossed. They are followed by another layer of a decomposed amygdaloidal lava which only persists for a few yards, to be replaced by the grey Carboniferous limestones again, striking north 30° west and dipping north-east at 51°. These limestones are traversed by joint planes separating them into large, rectangular blocks and they weather with smooth surfaces. When disintegration proceeds still further, they form stony hill-sides covered with reddish-brown soil and pierced by small isolated outcrops. The older metamorphosed limestones are always brecciated and form cliff exposures the surface of which is rough and honeycombed. The soil produced from them has a bright Indian-red tint.

The grey limestone bands are found for another 3 furlongs across the level summit of a small col until they are replaced at the foot of the last ascent to Teng-tzu-p'u by platy, yellowish dolomites with shelly bands, full of the fragmental remains of innumerable bivalves and other fossils. The rocks on this ascent are very varied and complicated and the sequence as far as I was able to make it out was as follows, commencing from the bottom of the hill :—

(1) 35 feet of reddish-brown, fine-grained, shale-like tuffs.
(2) —?— feet, hard earthy limestone with numerous broken fossils on the bedding planes.
(3) 12 feet, greyish marls with hard bands.
(4) A thin band of greyish-white, porcellanous limestone with dendritic markings, 6 inches thick.
(5) 8 feet, light red shales.
(6) A band of earthy limestone with fragmentary fossils, 4 inches thick.
(7) 3 feet of reddish shales.
(8) 7½ feet of massive grey limestones with yellow patches and calcite veins.
(9) —?— feet, reddish shales.
(10) 18 feet greenish-grey marls and reddish-brown shales, with two thin limestone bands.
(11) 3 feet massive, whitish-grey limestone.

(12) 13 feet, reddish shales.

(13) 8 feet, yellowish dolomitic limestone.

These rocks are very disturbed and the strike can be seen veering round from a few degrees west of north to north-west. For 200 yards beyond the yellowish, dolomitic limestones mentioned above, a thick layer of soil hides all exposures, but above this, the massive, grey limestones crop out again in thick, independent bands, and between them and Teng-tzu-p'u there are rapid alternations of igneous bands, red tuffs and thin limestones. I cannot give a continuous sequence of these rocks, as the road crosses fields of peas and tobacco amongst which they are found and by which they are partly covered. The strike of the limestone bands is, however, north 20° west and the dip north of east at 77°. It is probable that the high outstanding ridge or shelf on which the village is built is formed of the old metamorphosed limestone, the steep slopes above the road being covered with outcrops and fallen blocks of this rock. Above Teng-tzu-p'u there is a slight rise followed by a similar descent around the head of a small tributary valley, on the far side of which decomposed igneous rock is again overlain by a bold limestone scarp, which strikes north-north-west—south-south-east. This igneous band replaces the limestone about a furlong from the village. The pass itself is reached about 2 miles from the village at an elevation of 6,800 feet and on both sides the old metamorphosed limestone crops out. To the east a high, conical, limestone hill rises, and the small cultivated area further down is bounded by cliffs of the same rock. The village of Lushui lies just below the pass, and a little further on, the platy grey and bluish limestones of the Carboniferous were again found with a north 15° west strike and a dip of 63° towards the east. The track now winds around the small, cup-shaped depression below the village, crossing reddish and bluish shale-like tuffs which are succeeded by a thin band of decomposed lava. As the road turns east along the side of the spur with the narrow valley of the Shih-tien Ho on the left, the old metamorphosed limestones are seen again, rising up to form the crest of the conical hill which was observed from the pass, and along the flanks of which the road now runs, to the lower village of Lu-shui around which limestone cliffs rise. In the village itself, and as good exposures in a small stream just below it, are rounded masses of a greyish-blue igneous rock containing bands of an amygdular cha-

racter. The track now continues north-north-east down the side of the narrow, ravine-like valley of the Shih-tien stream for 3 or 3½ miles to Wan-chia-tien. The grey limestones of the Carboniferous come in immediately after the igneous rock, which does not persist more than ½ furlong beyond the stream, and are seen all the way down to Wan-chia-tien as greyish-white limestones which break with a conchoidal fracture and form the usual, small isolated outcrops. Certain bands in the rock mass have an oolitic appearance, and from others I obtained a few corals. On the surface of a limestone block used in the building of a house in Wan-chia-tien I saw two Spirifers.

From Wan-chia-tien a march of 10 miles in an easterly direction leads to the Shih-tien plain. Just above the village, thinly-bedded limestone bands strike north 28° west and dip towards the south-west at 25°—30°. For the first ½ mile limestone shales continue, but at ¾ mile they are replaced by thick bands of greyish-black, calcite-veined limestone which continue down to the Shih-tien Ho at mile 3¼, elevation 4,300 feet. They form small cliff exposures of a light reddish-brown colour above the bridge which crosses the stream. From the latter there is a slight ascent to the small alluvial plain of Hsiao-pai-i, which is only about ½ mile across, and which is watered by a small tributary of the Shih-tien Ho. This stream has cut through the alluvial deposits to the rock below, and good sections of the sand and pebble beds which fill up the plain are to be obtained. Immediately on leaving it the ancient metamorphosed limestone series is again found all the way up the steep ascent to Hsiao-shui-ching which has an elevation of 6,060 feet and is reached 2½ or 3 miles further on. Just beyond this village, at the head of a small valley running south-west, laminated grey limestones and calcareous shales with bands of calcite crop out, but from this point to the top of the ridge which borders the Shih-tien plain on the west, at an elevation of 6,850 feet, I only found two exposures, one consisting of platy limestones and drab shales, striking north-east and dipping at high angles to the north-west, and the other of decomposed yellowish shales. The rest of the sequence is hidden beneath pine forest and the thick soil with which this kind of vegetation is always associated. Going down the hill to the Shih-tien plain which has an elevation of 5,100 feet (Plate 26, upper figure) and lies 1½ miles further on, I discovered the fossiliferous series of Ordovician and Silurian strata which

I have already discussed in a previous paper of this series, and which has yielded such interesting palæontological results in the hands of Mr. Cowper Reed. (Plate 24, upper figure.)

TRAVERSE No. 6.

From the Shih-tien plain to Shun-ning Fu.

These two places are about 70 miles apart, and the journey between them was done in six marches, the first of which led southwards from the plain, after which the road proceeded in a more or less easterly direction, with a few local changes, across country drained by the Wan-tien Ho and its tributaries, affluents of the Salween and the Mong-you Ho which flows into the Mekong.

The alluvial plain of Shih-tien has an elevation of 5,100 feet above the level of the sea. On the west it is bounded by steep slopes which end in a straight sky-line, but on the other side, especially to the south-east, the heights have a very irregular outline. By the aid of a telescope I could make out the purple shales which seem to constitute the lower parts of these ranges, but towards the end of the valley on the western side, well-marked limestone scarps are to be seen. The plain is left behind about one mile beyond Shih-tien, and the road running in a south-east by south direction, ascends very steeply from 5,100 to 6,400 feet in 3 miles, to the crest of a ridge which divides the watershed of the Shih-tien Ho from that of the Yao-kuan Ho, a tributary of the Wan-tien Ho. On the ascent I found poor outcrops of sandy shales and soft, yellowish sandstones with a few reddish-purple shales somewhat higher up, for the slopes around are covered with soil and grass often overgrown with scanty pine forest. The actual road-way is partly paved with limestone setts, some of which are greyish and calcite veined, while others are reddish or reddish-pink in colour, of a lenticular structure, showing sections of *Orthoceras* and crinoid stems on their polished surfaces. At Ta-p'ing-ti, the small village situated at the summit of the ridge, a light grey, earthy limestone crops out in bands about 3 feet thick, which dip east at 15°. An excellent section of this rock may be found near the way-side shrine just below the village. From this point the road descends gradually

into the valley of the Yao-kuan Ho, in a southerly direction. The flat land on each side of the stream is terraced for rice cultivation, and the rare exposures which were seen consisted of red marls and soft, rotten, sandy beds, until at that point where the road crosses the main stream, thinly bedded, dark grey limestones were first found. Looking towards the south there is a large, conical, limestone hill forming a prominent feature of the landscape, and to the east of it another well-marked limestone bluff exists. Decomposed purple shales are found below the limestones and just where the road enters the long, narrow plain which extends, for 3½ or 4 miles, as far as Yao-kuan, there is a poor section exposing very contorted, soft, yellowish, sandy beds and reddish and reddish-purple shales apparently invaded by a dyke rock, but the whole outcrop was so excessively decayed that the nature of the latter could not be determined. Immediately beyond this, crushed and metamorphosed greyish-white limestones come in and grade imperceptibly into typical, unaltered, dark grey, crinoidal limestones of the Carboniferous. The actual contact of the limestones with the shales is hidden by the soil of the valley, but the extensive metamorphism of the rocks on both sides of this line lead me to suggest a fault as the junction of the two series which seem to belong to the Ordovician and the Permo-Carboniferous respectively.

Below this point there is a small lake, evidently the remains of a very much larger one which once filled the valley and gave rise to the alluvial and lacustrine deposits which it now contains. It is surrounded on three sides by limestone scarps which form rugged tops to the surrounding hills. Near Yao-kuan a series of soft yellowish marls irregularly marked and striped with red was found. A careful search in these only revealed the presence of doubtful remains of graptolites. Where the bridge crosses the main stream above Yao-kuan for the last time, purple slates crop out, and are succeeded by thinly-bedded and highly contorted limestones at a place where a large spring gushes out from the edge of the rice plain. I crossed over these sections after nightfall and could not make a detailed examination but I believe that they belong either to the Ordovician or the Silurian.

The next stage beyond Yao-kuan leads to Wan-tien, a distance of 11 miles. For the first half of the march the road proceeds in a south-easterly direction, afterwards turning to the east. After leaving the small Yao-kuan plain, poor exposures of decomposed,

variegated shales are passed as far as Hsi-pa, where drab and grey, lenticular limestones very similar to the Ordovician limestones crop out beside a spring which issues from below the road. The small Pai-ma valley is now crossed, the road running straight across it.

On the ascent out of it, to the south-east, dark greyish-blue, crinoidal limestones were seen but they are quickly replaced by massive, black, micaceous slates, much broken and jointed, stained yellow and brown at the outcrops, and doubtfully striking north 20° east. From these beds I obtained *Monograptus*, which proves their Silurian age. At 4 miles, yellowish and greyish-white micaceous bands were found interbedded with the black slates, after which the road enters a narrow ravine formed by the bed of a small stream flowing straight across the strike of the strata (Plate 23). As the road ascends this valley, the black slates are replaced by purple varieties which dip and strike in the same directions. Towards the summit exposures become fewer. Crossing under a small wooden arch erected over the road, a common Yünnanese method of denoting the top of a pass, a very extensive view of the country to the south and south-east is obtained. The sides of the valley below, formed by a small tributary of the Wan-tien Ho, rise steeply for almost 2,000 feet, and the valley of the parent stream itself is also very deeply excavated. Indeed the general features of this region forcibly recall those of the main Salween valley. The road proceeds along the northern ridge for 4 miles attaining an elevation of 6,800 feet at 8 miles. There is a remarkable paucity of rock exposures owing to thick soil and grass covering the hillside; however, I noticed bleached slates, which appear to be much the same as the purple slates found in the ravine further west, but discoloured by exposure,—and also harder and more arenaceous, yellow shales. Near the village of Ma-i-tsun, purple slates occur which are not metamorphosed and contain small crinoid stems. These rocks are easily distinguished from those of the older Kao-liang series as they are massive, and do not break easily, whilst their bedding planes are hardly marked at all. From 8 miles a long descent commences which becomes steeper at the bottom near the Wan-tien plain, reached at 11 miles, at an elevation of 2,600 feet. As the road zigzags down through thick jungle there are plenty of rock exposures as the soil cover is not thick. For the most part they consist of a uniformly hard, reddish-purple mudstone

or slate, with a very fine-grained matrix often speckled with tiny, glistening films of mica. I sought carefully for organic remains all the way down but only discovered a few small, crinoid stems and one doubtful cystidean plate, too fragile to carry away. The strike is usually constant at about twenty degrees east of north, sometimes the angle was a few degrees less, and lower down it veered round to the north and south with a dip of 45° to the west. These beds vary little in colour except in situations where they have been long exposed to the action of the weather and sun, when a bleaching takes place resulting in a patchy coloured rock of yellowish shades mottled with grey. In the last 1½ miles a greyish-white shale is followed by thin limestone bands, yellow, grey, pale pink and mottled bluish-white and grey in colour. Some of these bands contain abundant crinoid stems. They break with a rough fracture and are then seen to be reddish-yellow and mottled grey rocks intersected by thin, calcite-filled gashes. They disappear under the alluvium of the valley plain.

The Wan-tien plain appears to be of alluvial origin and is not an old lake basin. The pebbles brought down by the river are composed of sandstone and dark limestone. The Wan-tien Ho is known to the Shans, who inhabit its deep valley, as the Nam Hka, and is the southern continuation of the stream which drains the large Yung-ch'ang Fu plain. It is crossed by a ford at 1½ miles, whence the road commences to ascend gradually across poor exposures of soft, speckled, greyish-yellow sandstones with decomposed shales in places. At about 3 miles, 3,100 feet elevation, thick forest is met with making geological work almost impossible. It continues until the 5th mile, at 4,800 feet, when the climb becomes a more gradual one again. At 5,200 feet, about 6 miles from Wan-tien, very decomposed reddish and yellowish-white marls were seen, but I could not find any fossils in them. Still ascending, the route passes Ta-p'ing-ch'ang, where I noticed black shales with thin, interbedded, limestone layers, while towards the east there is a bluff of massive limestone forming the top of a hill which bounds the little Ta-p'ing-ch'ang valley. At that point where the stream is crossed beyond the village, limestone bands of greyish-white and dark crinoidal varieties, alternate with dark shales, which seem to dip towards the south-east. After climbing up out of Ta-p'ing-ch'ang there is a slight descent to another small stream running towards the north, and on the road down I found

reddish-purple shales. Slowly rising up the left bank of this narrow valley, the road now passes directly underneath the limestone bluff which was found to be made up of greyish-white, intensely metamorphosed limestone. A small landslip on the opposite side had exposed thin alternations of reddish and greenish shales, hard sandstone bands, layers of carbonaceous shale and thin seams of impure coal, which appear to be long drawn out lenses, rather than well-marked seams. This succession seems to underlie the metamorphosed limestone, but the exposures are too poor to enable me to be confident on this point. The limestone continues in typical outcrops and large fallen blocks until the final steep ascent to Kan-kou, which occupies ½ mile, is reached, when it is followed by poor exposures of a decomposed igneous rock, certain portions of which are amygdaloidal.

From Kan-kou a march of 13 miles brings one to the Ta-mung-t'ung plain, the general direction being eastward and the elevation dropping from 6,500 feet at Kan-kou to 3,750 feet, the general altitude of the plain. From the top of the first hill, shortly after leaving the village, scarps of old, metamorphosed limestone are seen to form prominent features of the landscape towards the east and north-east. In the third mile a short detour to the south-east is made, and near Ma-li-tsun, a small hamlet of two or three houses, sandy yellow marls crop out. At the highest point attained, that is 6,900 feet at 5 miles, hard, light sandstones are exposed. The surrounding country is covered with thick forest, with a few clearings under hill cultivation, grass or bracken, and it was very difficult to see anything of the rocks beneath. At 6 miles, I noticed pale red sandstones with darker bands of a terracotta shade alternating with pale pink and mottled pink and white, soft sandstones and an occasional thick bed of dark grey sandstone. The series is unfossiliferous and strikes north 25° west. There is now a descent to a small stream at 6½ miles, elevation 6,400 feet in the bed of which there are sections of hard, greyish-yellow sandstones. Just below the village of Pa-ta-shan, thin beds of soft sandstone strike north 10° west and dip towards the east at 68°. ½ mile up the stream which runs down the small valley in which this village is situated, massive conglomerate bands, the biggest of which is 30 feet thick, strike north 20° west and dip towards the east at 40°. They contain large pebbles of quartz, quartzite and sandstone. Before breaching the conglomerate bands the stream flows along the strike from the

north down a small, alluvium-filled valley formed at the junctio of the conglomerates and the soft shales, which build low, rounde hills on the east, in marked contrast with the bold relief of th conglomerates. The red shales are followed by hard sandstone along which the track proceeds for ½ mile, perched high up nea the top of the dip-slope, before turning down a small ravine covere with thick jungle growth and opening out towards Chin-mu-lin at 8 miles, elevation 6,000 feet. This place is situated near th crest of the high ridge which confines the Ta-mung-t'ung valle on the west, and the latter is first seen from a point just above i Towards the north the broken country in the direction of Yo tien is visible; to the east the bounding wall of the Ta-mung-t'un plain, and towards the south the high ridge which runs south-we from Shun-ning Fu, with peaks reaching an elevation of over 11,00 feet and dividing the waters of the Nam Ting from the strea further north. Down to Hsiao-chai, at an elevation of 4,500 fee the road winds through very forest-clad country in which there a no good exposures though a few poor outcrops of bleached san stones and red shales were seen. From Hsiao-chai to the plain 13 miles, elevation 4,000 feet, there are exposures of dark, bioti schists, dark, greyish-blue phyllites and finely laminated, muscovi phyllites, typical rocks of the Kao-liang series. The alluvial deposi which fill up the valley are made up of slightly cemented pebb beds, sands and sand rock.

A march of 15 miles from Ta-mung-t'ung in a general nort east by easterly direction leads to the Mung-you plain at an el vation of 5,500 feet. For a mile or so the road follows a nort easterly direction and then turns more to the east along a spu at first on the northern side, and later on the southern one, b on both sides above deep valleys drained by small streams runni down to the Ta-mung-t'ung Ho. The ascent leads gradually to Ch'a-lu-kai at an elevation of 6,000 feet. The whole area thickly wooded and exposures are exceedingly infrequent and poc but the ones which were seen consisted of the same types of ro as those found on the descent down to Ta-mung-t'ung,—deco posed mica schists, bleached phyllites and an occasional qua vein. At the top of the ridge an extensive view to the south obtained. On the opposite side of the small tributary valley great cliff-like exposure of limestone forms the sky-line. The s rounding country is very cut up into steep-sided, narrow ridg

with deep valleys between them. (Plate 26, lower figure.) On the descent, at 9 miles, greyish-blue, calcite-veined, limestones crop out, forming two prominent hills close to the road. All the way down to the plain rocks of the old Kao-liang system continue in the form of reddish and variegated, fine-grained, micaceous schists, dark phyllites and a few bands of quartzite. Quite close to the plain there is a good exposure of one of these latter. In the bed of the Mong-you Ho I noticed pebbles of similar rocks. The plain itself is of alluvial origin and the villages are built on outlying spurs which overlook the rice lands of the valley.

From Mong-you to Shun-ing Fu is a distance of 12 miles in an easterly direction.

After crossing the plain a steep ascent commences through a cutting in which micaceous phyllites with numerous quartz lenticles are exposed. At 3 miles the strike is north and south and the dip at 58° towards the east, though at the same time there is considerable folding and contortion in these strata. Identical rocks continue to the top of the ascent at 6½ miles, elevation 7,500 feet. At this point a fine-grained granite crops out in good exposures which continue for 1 mile and are then replaced by the phyllites once more. From the summit the general direction to Shun-ning Fu is south-easterly, and the phyllites fill up the ground until about two miles from the city the intrusive granites occur again. The elevation of Shun-ning Fu is 5,800 feet, and there is practically no valley plain though a little alluvium exists on both sides of the river in the vicinity. On the other hand, the hill-sides are terraced to a height and degree which I have never seen equalled anywhere else in Yünnan.

TRAVERSE No. 7.

From Shun-ning Fu to Yung-ch'ang Fu.

Around Shun-ning Fu there is a great development of white granite which appears to me to be intrusive into the old rocks of the Kao-liang group.

The first stage of 12 miles from Shun-ning Fu, which has an elevation of 5,800 feet, led me in a general westerly direction to Mong-you. As I have already given an account of the geological features of this journey before, it is unnecessary to repeat them here. The general direction of the route I followed from this point

was towards the north-west and I estimate the distance between Mong-you and Yung-ch'ang Fu at about 60 miles.

The second stage leads to the village of Hsiao-chiao, 12 miles. The road follows the course of the Mong-you Ho, a tributary of the Mekong, in a westerly direction for 3 miles and afterwards to the north-north-west, at times close to the river, and at others across spurs further away from it. The Kao-liang series continues the whole way, but owing to thick common jungle and pine forest, exposures are poorer even than usual and it is impossible to record a connected sequence. Hard quartzites, biotite phyllites and greyish, micaceous rocks are the commoner types. Owing to their disturbance and decomposition at the surface no dip or strike observations were taken.

Still ascending the valley of the same stream the next march leads to the town of You-tien, a distance of 12 miles. On the western side of the valley just opposite Hsiao-chiao, a hot spring issues from beneath a limestone bluff. There is a copious discharge of hot water and a strong smell of sulphuretted hydrogen in the immediate neighbourhood. The limestone is chalk white in colour and overlies the older strata, for decomposed quartzitic grits and slates crop out in the stream-bed just below it. As the road continues along the east bank of the river it crosses similar rocks, but on the opposite bank the limestones can be seen. Crossing by a bridge at Ta-chiao there is an ascent up a steep hill-side covered with limestone outcrops. At first they are like those found lower down stream, that is, brecciated and unfossiliferous, but after crossing the summit of the ridge darker grey limestones were found which appeared to contain fragmentary fossil remains. I regard the latter as belonging to a Carboniferous horizon higher in the sequence than the brecciated ones, which were again met with as hard, broken, pink and white bands, at the descent to a small stream just before the village of Ho-mu-chia or Ho-pien was reached.

Between this point and You-tien (elevation 5,900 feet), when not on the alluvial deposits of the river, I crossed coarse felspathic grits and fine-grained, silver-grey phyllites. Near You-tien there are the remains of a high-level river terrace 20—30 feet above the present stream-bed. On this march I noticed much dry cultivation on the slopes, but the ascents and descents are not great, though the area is a very dissected one. The smaller ranges have no

continuous well-marked direction but to the north-west there is a fairly high ridge.

Soon after departing from You-tien I left the main Yung-ch'ang Fu road which then crosses the ridge separating the valleys of the Mung-you and Wan-tien Ho's, and entered unsurveyed country to the north-west and north. Owing to this I am not able to locate exactly the boundaries of the various formations crossed, and my map of this particular region is not intended to be more than a general approximation to accuracy. For two days I wandered in various directions across deeply dissected country, covered for the greater part with forest, and made up of rocks of the Kao-liang system. Only poor exposures were met with, but they were sufficient to prove that slates of reddish and bluish shades with quartzite bands and a few thin quartz veins were the typical rocks. They often had a dip of 30°-50° approximately to the north-east. Further to the north, that is to say in the area which lies about half way between You-tien and Yung-ch'ang Fu as the crow flies, the valleys become deeper and the ranges more individualized. Their tops have an irregular broken outline and the main spurs run east and west, between what appeared to me to be the smaller tributaries of the Wan-tien Ho. Between Mai-tzu and Ping-tai, the Kao-liang rocks are well developed but further to the north and north-west, limestones cover the greater part of the country. High arid, stoney ridges run in an approximately north and south direction, and judging from the serrated peaks to the south-west, stretch far away in that direction too. Before the Yung-ch'ang Fu plain was reached I crossed an undulating rocky plateau traversed by low limestone ridges. (Plates 25.)

EXPLANATION OF PLATES.

PLATE 21.—{ The Mekong valley N. of Shun-ning Fu.
The Shweli and its terraces at Kan-lan-chai.

PLATE 22.—{ The Hsia-Kuan Ho breaking through the T'sang Shan range.
The Mekong gorge below Shui-chai, Yung-ch'ang Fu.

PLATE 23.—Ravine between Yao-Kuan and Wan-tien.

PLATE 24.—{ Lower Ordovician rocks west of the Shih-tien plain
Limestone hills in Salween valley below La-mêng.

PLATE 25 —{ Limestone country, S. E. of Yung-ch'ang Fu.
Granite-country between Lung-ling and Tuan-chia-chai.

PLATE 26.—{ The Shih-tien plain.
Country west of Mong-you, Shun-ning Fu district.

PLATE 27.—The Yüng-ch'ang Fu plain.

PLATE 28.—Map of Yünnan.

A FOSSIL WOOD FROM BURMA. BY MISS RUTH HOLDEN. (With Plate 29.)

THE extraordinary abundance of fossil wood to be found in Upper Burma has been noticed by all travellers in that region from the time of Crawfurd's visit in 1827[1] to the present date. So striking is its occurrence that the beds in which it appears were long known as the "Fossil Wood Group." More recently, however, a certain number of specimens have been found in the underlying Pegu series, so, to make the distinction between the two series clear, the name of the upper one has been changed to Irrawadian. As regards age, the former is referred to the Oligocene or Miocene ; the latter to the Pliocene. The manner of preservation has been a subject of more or less controversy, Buckland[3] states that part is calcified and part silicified ; Theobald[4] asserts that "none of the fossil wood is mineralized by calcification," and this observation is confirmed by Oldham.[5] Pascoe,[2] however, says that both types of petrifaction are to be encountered, though the former is the more common. The nature of the wood has always been a mystery. Buckland[3] suggested that it resembles the tamarind, but presented no evidence pointing to such a conclusion. On the other hand, the natives of Pegu[6] claim to be able to recognize two varieties, one of which they identify as the modern Enjin tree (*Hopea suava*) and the other as the Thiya (*Shorea obtusa*). In order to settle the matter, Theobald in 1867 sent some specimens to the British Museum for microscopic examination, but the preservation proved to be so unsatisfactory that it was only possible to ascertain that it was exogenous, not coniferous. Even in 1895, Noetling[7] comments on the fact that though quantities have been brought to England, no scientific investigation has hitherto been made. In 1914, however, Mr. F. W. Cuffe, presented to the Sedgwick Museum, Cambridge, a calcified specimen from Gwedindon in the Sagaing District. This

[1] Crawfurd, 1827.
[2] Pascoe, 1912.
[3] Buckland, 1828.
[4] Theobald, 1873.
[5] Oldham, 1855.
[6] Theobald, 1869.
[7] Noetling, 1895.

was submitted by Dr. Arber to the writer for sectioning, and although the condition of the tissues leaves much to be desired, it is believed that its miscroscopic structure may be made out with sufficient detail to warrant description.

The material consists of two blocks, each about ten inches long, composed exclusively of secondary xylem. In the hand specimens, the annual rings appear to be well marked, averaging from ·3 to ·9 cm. in width, but as will be explained later, one cannot be sure that these correctly represent yearly increments of growth.

When studied microscopically, the preservation is seen to be very uneven, indicating that the wood had partially decayed before petrifaction took place. By a careful examination of selected areas, it is possible nevertheless, to ascertain the structure in considerable detail. The general features of the transverse section are indicated in Pl. 29, figs. 1 and 2. The vessels are very large and are scattered uniformly throughout the wood, without the differentiation into spring and summer elements characteristic of ring porous woods. As a rule, they are isolated, though at times they form radial groups of rarely more than three or four. The walls are comparatively thick, and abundantly pitted, especially where they are in contact with the cells of the rays. The character of the end walls could not be made out, but the study of living woods indicates that this is not a feature of any great diagnostic importance. Thus, while the more primitive types, such as *Betula* and *Alnus*, generally have scalariform openings, and the higher ones,—the Leguminoseæ—, have one large pore, many of the Fagaceæ combine both types. An extremely constant feature, however, is the abundance of tyloses which seem to fill completely the lumen of every vessel. These usually contain a dark resinous substance.

The rays contain this same substance, which causes them to stand out in the photographs. As shown in figures 2 and 3, they are ordinarily one cell wide, and vary from six to twenty cells in height. In the radial sections (figs. 4 and 5), the individual cells are seen to be rectangular in shape, while those on the margins not infrequently tend to become higher and more nearly square than those in the centre. Indications of such a condition may be discerned on the lower margin of the ray shown in figure 4, but it is far from being universal.

Wood parenchyma is very abundant, and occurs in two definite positions, around the vessels and in tangential rows. In general,

the vessels are so large and the rays so close, that each vessel is necessarily bounded radially by a medullary ray. Tangentially there are always wood parenchyma cells, thus ensuring a parenchymatous jacket completely encircling each vessel. This probably explains to some extent the uniformly tylosed condition of the vessels ; it is represented in transverse section by figure 2 ; in longitudinal, by figure 5. The occurrence of wood parenchyma in tangential bands of two to four cells is equally constant (see figs. 2 and 5). A striking feature is that these bands are nearly always double. In the description of gross specimens, it was mentioned that annual rings appear to be very clearly marked, but when subjected to microscopical examination, it is apparent that these "annual rings" are not formed by any difference in the size or thickness of wall on the part of the tracheides, but by these bands of tangential parenchyma. It is probable that at the close of each year's growth, the cambium laid down parenchyma cells, as in many of the living Leguminoseæ, etc.[1] ; but in view of the irregularities known to exist in the formation of annual rings by the tropical woods of to-day, it appears safer to leave the question open.

One other feature of this wood requires mention, but unfortunately the state of preservation renders a definite statement impossible. In the lower part of figure 1, a tangential series of cavities may be seen ; a single cavity is shown in longitudinal section to the left of the vessel in figure 5. Superficially they resemble the resin canals formed in many conifers as a result of wounding, or the "gummosis" of certain Rosaceæ. A closer parallel is probably afforded by the tangential bands of secretory canals found in many of the Dipterocarpaceæ. They occurred but once, however, in the material sectioned, and unfortunately in one of the least well preserved regions.

To sum up, the salient points in the anatomy of this wood are :—

(1) Vessels large, isolated, uniform in size throughout the year's growth, usually completely tylosed, and often filled with resin.

(2) Rays one cell wide, six to twenty cells high, very resinous, marginal cells often higher than those in the centre.

(3) Wood parenchyma vasicentric, and forming tangential bands.

(4) Tangential rows of secretory canals (?).

[1] Holtermann (1907).

We come now to a consideration of the systematic position of this wood. As noted above, the two previous suggestions have been to the tamarind, and to the Dipterocarpaceæ. In microscopic structure, there seems to be little reason for the former reference, and the fact that *Tamarindus* is not indigenous in Burma,[1] renders this suggestion improbable. As regards the Dipterocarpaceæ, there is much to be said for this view. Through the kindness of Dr. Dawson of the Cambridge Forestry School, the writer was enabled to examine specimens of *Hopea odorata* and of various species of *Shorea*, and though specific identification with the fossil was not possible, they are clearly all of the same general type. The best description of the wood of the Dipterocarpaceæ is given by Brandis and Gilg.[2] According to them, there is an abundance of resinous substance in the resin canals, rays, wood parenchyma and vessels ; the rays are up to six cells wide, and consist of " liegenden und stehenden Zellen ;" the vessels are large, usually isolated, rarely in radial rows ; the resin canals are often in concentric circles, but are frequently sparingly present. With regard to the individual genera, *Shorea* seems nearest to our fossil, with " Gefässe meist einzeln ; Markstrahlen fast ganz aus liegenden Zellen bestehend, mit einzelnen kubischen Zellen aus oberen und unteren Rande. Holzparenchym um die Gefässe und in feinen 1-schichtigen Querbänden zwichen den Markstrahlen." Solereder[3] states that the rays of the Dipterocarpaceæ are 3—5 seriate, and the wood parenchyma abundant ; while Guérin[4] comments especially on the large number of tyloses in the vessels. According to his observations, the resin canals are extremely sporadic, being sometimes entirely absent. To sum up, the features in which this Tertiary wood resembles that of the living Dipterocarpaceæ seem to be—

(1) Vessels large, usually isolated, abundantly tylosed, and filled with resin.

(2) Rays highly resinous, marginal cells higher than the central ones.

(3) Wood parenchyma tangentially banded, and vasicentric.

(4) Resin canals lacking, or in tangential rows.

[1] Brandis, 1906, p. 253.
[2] Brandis and Gilg, in Engler and Prantl. 1895, III 6, p. 266.
[3] Solereder, 1899.
[4] Guérin, 1907.

Recent work on the comparative anatomy of angiosperm woods has emphasized the diagnostic importance of the position of the parenchyma, and on that character alone, one would be almost justified in referring this specimen to the Dipterocarpaceæ. The only discrepancy is the width of the rays, which according to descriptions referred to above, are at least three cells wide. In one species, however, *Shorea polyspermea,* I found them often uniseriate, and rarely more than di- or tri-seriate. This character, moreover, is always variable often within the genus,—*e.g.*, both *Salix* and *Populus* contain uniseriate and diseriate rayed forms.[1] As some evidence corroborating the reference of this wood to the Dipterocarpaceæ Heer's description of *Dipterocarpus verbeekianus*, and *D. antiguus*,[2] from the Tertiary of Sumatra, is of interest.

We may then appropriately call this fossil *Dipterocarpoxylon burmense,* with the characters defined above.

In conclusion, I wish to thank Dr. E. A. Newell Arber for an opportunity to describe this wood ; Dr. Dawson of the Cambridge School of Forestry for specimens of living representatives of the Dipterocarpaceæ ; and Professor A. C. Seward for kindly reading the manuscript.

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DESCRIPTION OF PLATE.

FIG. 1.—Transverse section, showing tangential series of resin canals (?).

FIG. 2.—Transverse section showing vessel filled by tyloses ; narrow medullary rays, parenchyma vasicentric, and in tangential bands.

FIG. 3.—Tangential section, showing narrow rays, and tylosed vessel.

FIG. 4.—Radial section, showing character of rays, and wood parenchyma.

FIG. 5.—Radial section, showing tylosed vessel, and vasicentric parenchyma.

THE VISUNI AND EKH KHERA AEROLITES. BY H. WALKER, A.R.C.S., *Assistant Superintendent, Geological Survey of India.* (With Plates 30 to 33.)

THE purpose of this short paper is to put on record the details of the descent of two meteorites which, having recently fallen in India, are now in the custody of the Geological Survey of India; to give descriptions of their general appearance; and to put forward some observations of their petrological structure.

I.—The Visuni Aerolite.

On the 19th January 1915, near the village of Visuni in Sind a meteorite fell. This meteorite, under the name of "Visuni," has now been added to the collections of the Geological Survey of India in the Indian Museum, Calcutta. Its registered number in the collection is 266.

Account of the Fall.

This meteorite, and an account of its fall, was obtained by the prompt action of Mr. N. B. Mahomed Husain, Deputy Collector of the Nara Valley, Sind, who himself heard the sound of its flight. The stone was forwarded to the Collector of Thar and Parkar (G. E. Chatfield, Esq., I.C.S.), by whom it was sent to the Geological Survey of India. The account sent by the Deputy Collector is as follows :—

"I..........submit herewith vernacular statements of Bheru, Banko, and Khan Mahomed taken by the Head Constable, Chor, regarding the fall of an asteroid in the vicinity of the village Visooni[1] in the Umarkot Taluka and to state as under :—

"On the 19th January 1915 at about noon, a sharp thundering sound was suddenly heard from the sky in the village of Visooni and immediately afterwards Bheru and others saw a stone fall on the ground some 100 paces towards the east of their houses. Banko with other boys went after it and noticed a piece of meteorite lying at the place. It was perceived to be somewhat warm and had partly forced its way into the sand where it had fallen. Having

[1] The Hunterian spelling of the word is employed in the text of this paper.

secured it the boys dug about a cubit deep into the ground but nothing else was found."

"I am informed that the sound was audible throughout the Umarkot Taluka and was even heard in Shadi Pali and Samaro. It was heard by me at Dhilyar in Khipro Taluka also."

"The aerolite is of blackish colour and weighs 52½ tolas. A portion of it was broken by the finders to satisfy their curiosity. It is submitted herewith for favour of transmission to the Government Geological museum in Calcutta."

Location of the Fall.

The name Visuni is not to be found on the maps of the area. Further correspondence through the Collector of Thar and Parkar elicited the fact that the meteorite fell at the village formerly known as Besoee jo Turr, which is in Lat. 25° 27′; Long. 69° 58′ (corrected) and is situated 15 miles E-N-E. of Umarkot. This name has fallen into disuse and the village is now known as Visuni.

With reference to the sound of the flight being heard over a considerable area it is interesting to note that Samaro (Samara) and Dhilyar (Dhiliar), two places mentioned by the Deputy Collector of the Nara Valley, are respectively 32 miles W. 14° S. and 36 miles W. 33° N. of Visuni. I could not find the third name, Shadi Pali, on the map.

General Description of the Aerolite.

The aerolite as received by the Geological Survey weighed 594·1 grammes, but after a small piece had been removed for the purpose of preparing a microscope slide it weighed 593·36 grammes. It is an almost complete and well preserved specimen. In shape it is six-sided; is roughly rectangular; and in nearly all parts the edges are well marked. From four corners small pieces of the crust have been knocked off and from a fifth a larger area, roughly one square inch, is missing (Pl. 30 & 31). In colour the crust is dull black to shining black with patches of grey-black in places. 'Thumb-marks' are fairly distinct on one surface (Pl. 30, fig. 2) and less distinct on two others (Pl. 31, fig. 1). Lines of 'flow-structure' are to be seen on two faces (Pl. 30, fig. 1, Pl. 31, fig. 1) and they radiate from one corner (A) in such a way as to suggest that this corner was the foremost part of the meteorite during its flight. Further, faint indications of 'flow-structure' are to be seen on one of the thumb-marked faces (Pl. 30, fig. 2) and they, also, appear to radiate from the above mentioned corner. The crust in different parts varies in thickness but

not markedly so. It is thickest at the corner which I regard as the foremost during flight and is thinnest at the corner diametrically opposite, *viz.*, the portion where most crust is missing. One minute vein of nickel-iron is to be seen. Its trace on the surface of the meteorite truncates three corners.

Description of the fractured surfaces.

The colour of the fractured parts shortly after the receipt of the aerolite in Calcutta was blue-grey and speckled. The damp, warm atmosphere of Calcutta has caused the surfaces to show a certain amount of rusty brown colour. The interior is hard, crystalline, and chondritic. The chondrules are of two sizes. By far the major number are small, from 0·4 to 0·7 mm. in diameter, and are not fractured on the broken surfaces. A few of larger size are to be seen from 1·2 to 1·7 mm. in diameter, and some of them are fractured at the broken corners. Small, gleaming pieces of nickel-iron are scattered plentifully between the chondrules. These in the damp, warm climate of Calcutta, even during the period required for examination, are gradually becoming rusted over. On all the surfaces are pieces of a bronzy substance which when treated with dilute hydrochloric acid give off sulphuretted hydrogen. These are most probably troilite.

Specific Gravity.

The specific gravity of the meteorite was taken by immersing it in water, and the result obtained was 3·54. On taking the meteorite out of the water the surface was seen to be covered by a series of polygonal cracks similar to those seen in the 7 lb individual of the Modoc meteorite.[1] These cracks entirely disappeared when the meteorite dried.

Classification.

In attempting to determine the systematic position of this meteorite I have followed the practice of the Geological Survey in adopting the classification of Brezina as laid down by him in his recent paper on "The Arrangement of Collections of Meteorites."[2]

From the foregoing description it will be seen that this aerolite may be referred most naturally to one of the two classes, Crystalline Chondrite or Crystalline Spherical Chondrite. But the Visuni aerolite does not altogether fulfil the requirements of either class On the one hand very few of the chondrules break with the matrix

[1] Publication 122, Field Columbian Museum, Geological Series, Vol. III, No. 6, 1907, Plate XXXVIII.

[2] Proc., Am. Phil. Soc., Vol. XLIII, 1904, pp 211—247.

as required in the former class, and on the other, the matrix is firm and hard and not friable as required in the latter class. I have compared the Visuni aerolite with those contained in the collection of the Geological Survey and I have found that it is very like the St. Germain en Puel aerolite. I propose, therefore, to place the Visuni meteorite in the class: Stone, No. 37, Crystalline Spherical Chondrite, Cck of Brezina.

Microscopical characters.

In a thin section (No. 12,079[1]) under the microscope the aerolite is seen to consist mainly of olivine. The groundmass is composed chiefly of olivine forming aggregates as small chondrules; but there is a lesser amount of the mineral distributed throughout the mass as small, more or less idiomorphic individuals. One crystal—well shown in Pl. 31, fig. 2—has attained an unusual size. It shows crystal outlines; contains irregular patches of glassy material, and has a peculiar colour-band with pleochroism from a dull brown to a red brown. This colour-band is almost invisible when the crystal is in the position of extinction. The larger chondrules are very much fewer in number and are composed of radiating aggregates of enstatite. Nickel-iron is represented in the microphotographs by the black patches. It is irregularly disposed. In some parts of the slide it is seen to cling to the peripheries of the chondrules and in other parts it appears to have no relation to them. Here and there small pieces of olivine are enclosed in the mass of the nickel-iron.

II.—The Ekh Khera Aerolite.

This meteorite, No. 273 of the Geological Survey collection, fell in the *mauza* Ekh Khera on the 5th April 1916 but was not found until the 21st of the same month.

Account of the Fall and Find.

It was received by the Geological Survey through the interest of the Magistrate of Budaun, to whom it was submitted by Gauri Shankar, the Patwari of *mauza* Ekh Khera. A translation of Gauri Shankar's report of the occurrence runs as follows:—

"I beg to state that on 5th April 1916, at about 2-30 A.M., there appeared some light on the sky, which soon disappeared suddenly. Soon after this some 8 or 10 fire-balls were seen which seemed to be

[1] This is the registered number of the microscope slide in the collection of the Geological Survey of India.

coming down to the earth. This was followed by reports similar to that of gun firing and after this continued reports were heard like that of beating of tins.

"Next morning the cultivators proceeded to the spot where they suspected that something had fallen from the sky and searched there but nothing was found there. On 21st April 1916, some graziers found this meteorite which is said to have fallen from the sky."

From the foregoing report it is not clear whether or not the fall and find of the meteorite were at Ekh Khera. Enquiries on these points were addressed to the Magistrate of Budaun and by his courtesy the facts were made clear. He states "...... that the meteorite fell in Ikh Khera on the Islamnagar-Badaun road on the 5th April 1916. Many persons saw the meteor which before its fall presented the appearance of a large and luminous ball. In its transit it seemed to increase in size and coloured flames issued from it. This lasted for about two minutes and then after that darkness ensued and three sounds resembling the report of a cannon were heard in quick succession. A search was made without success on the following morning and the meteorite was not discovered till the 21st April 1916. It was found embedded in the ground and in removing it a portion was broken and has not been recovered. As far as can be ascertained only one fall took place and from the fact that the meteorite was found embedded in the ground it would appear that the fall and find were at one and the same place."

Location of the Fall.

The village of Ekh Khera lies in Lat. 28° 16′; Long. 78° 47′ (corrected), and is near the Islamnagar-Budaun road in the Bisauli Tahsil of the Budaun District of the United Provinces of Agra and Oudh.

General Description of the Aerolite.

The aerolite is an incomplete one with, probably, a little less than half its bulk missing. When received by the Geological Survey it weighed 840·3 grammes. In shape it may be likened to a somewhat obtuse scalenohedron with the lower apex removed. The prevailing colour is dull grey-black, but all over the surface are small, shining black points where metallic constituents have been fused. Minute brown patches are found all over the faces B and C and over the apex A (Pl. 32, fig. 1). These I regard as soil marks. If this surmise is correct, then the meteorite travelled with apex A as the foremost point and fell so that the apex and the ridge AD were buried in the

ground. I have been unable to detect any signs of 'flow-structure' in the crust, but the surface is very considerably scored by 'thumb-marks.' The crust is smooth, thin, and does not vary markedly in thickness. One small, fused, metallic vein is to be seen (Pl. 32, fig. 2, E). Polygonal cracks break up the crust of one of the faces (Pl. 32, fig. 2, F) in a manner similar to that in the Modoc meteorite (see footnote, page 275).

Internal Appearance.

The matrix is hard and firm. When the meteorite was first received the fractured surfaces were pale, bluish-white in colour. After some time in the warm, humid atmosphere of Calcutta they have become grey with red-brown rust spots. Originally it was difficult to detect the chondritic structure of the meteorite with the naked eye, but the colour changes have accentuated it and made it visible. The chondrules are small, on the average 1·0 mm. in diameter, and they break with the matrix. Figure 1 of Plate 33 reproduces the black veining of the meteorite. Some of this vein material has a bronze metallic lustre and some occurs in the mass of the meteorite as irregularly shaped plates (Pl. 33, fig. 1, G). This material evolves sulphuretted hydrogen when treated with hydrochloric acid and is, therefore, probably troilite. Small gleaming points of nickel-iron are thickly scattered in the matrix.

Specific Gravity.

The specific gravity of the meteorite was taken by immersing it in water. The result obtained was 3·71.

Classification.

I have compared this aerolite with those in the collection of the Geological Survey of India and I have found that it most nearly approximates to the Bori aerolite. I propose, therefore, to place the Ekh Khera meteorite in the class: stone, No. 19, Veined Intermediate Chondrite, Cia of Brezina.

Microscopical characters.

A microscope slide (No. 12,314) shows the meteorite to consist of nickel-iron, troilite, enstatite, olivine and felspar (?) with black material in veins which has not been determined. In the microphotograph (Pl. 33, fig. 2) the irregular black patches represent nickel-iron and troilite, which are fairly evenly intermixed in the mass. The grain of the meteorite is fine and the minerals are almost invariably granular. In one place in the slide there are phenocrysts of olivine enclosed in enstatite. The chondrules are chiefly aggregates of granular enstatite, but the one shown in the microphotograph has olivine near its periphery.

A colourless mineral of low double refraction occurs in small quantity. It shows indications of lamellar twinning and I have tentatively regarded it as felspar.

LIST OF PLATES.

The Visuni Aerolite.

PLATE 30.

FIG. 1. A general view of the aerolite showing the point (A) foremost in the flight and the lines of 'flow-structure' radiating from it.

FIG. 2. The face opposite to that shown in fig. 1. 'Thumb-marks' and lines of 'flow-structure.'

PLATE 31.

FIG. 1. A view of the aerolite in a position inclined at 45° to that shown in Pl. 30, fig. 1.

FIG. 2. A microphotograph of a thin section of the aerolite showing large and small chondrules and an olivine phenocryst. × 20 diameters.

The Ekh Khera Aerolite.

PLATE 32.

FIG. 1. A general view of the aerolite, the point (A) foremost in flight being uppermost.

FIG. 2. A view looking down on the apex of the aerolite.

PLATE 33.

FIG. 1. A view of the broken end of the aerolite showing the black veins and the clusters of plates of troilite.

FIG. 2. Microphotograph of a thin section of the aerolite. × 2 diameters.

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THE MEKONG VALLEY NORTH OF SHUN-NING FU.

Photographs by J. Coggin Brown. *G. S. I. Calcutta.*

THE SHWELI AND ITS TERRACES AT KAN-LAN-CHAI, TÊNG-YÜEH.

Records, Vol. XLVII, Pl. 22.

THE HSIA-KUAN HO BREAKING THROUGH THE T'SANG SHAN RANGE.

Photographs by J. Coggin Brown. *G. S. I. Calcutta.*

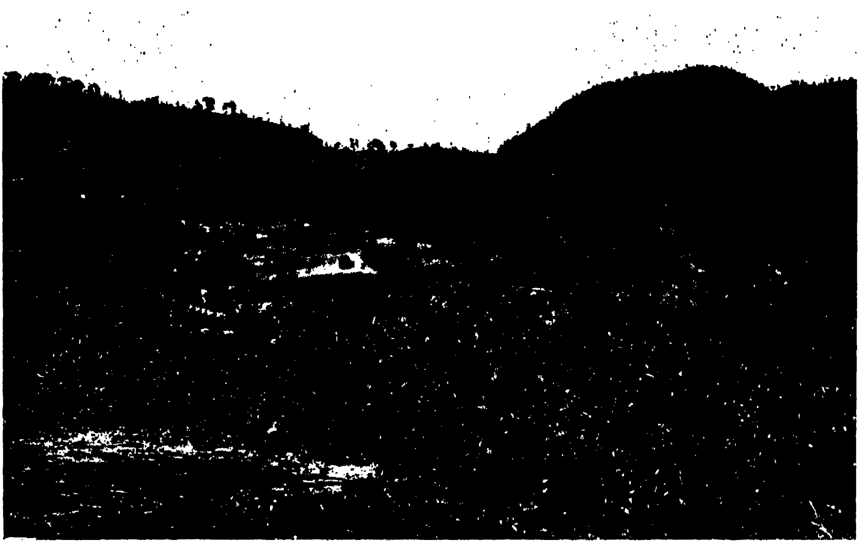
THE MEKONG GORGE BELOW SHUI-CHAI, YUNG-CH'ANG FU.

Photo by J. Coggin Brown. *G. S. I. Calcutta.*

RAVINE BETWEEN YAO-KUAN AND WAN-TIEN, TRAVERSE 6.

Records, Vol. XLVII, Pl. 24.

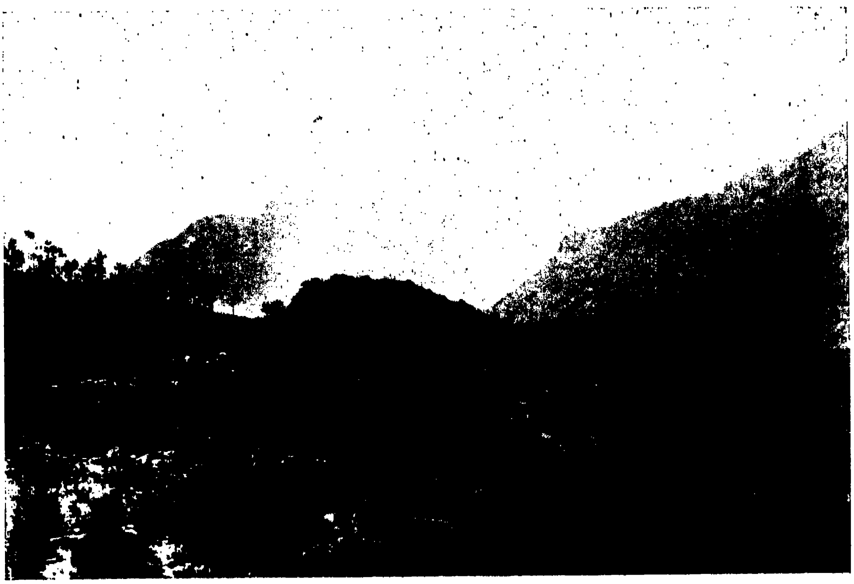
THE LOWER ORDOVICIAN ROCKS WHICH BORDER THE WEST OF THE SHIH-TIEN PLAIN.



Photographs by J. Coggin Brown. *G. S. I. Calcutta.*

LIMESTONE HILLS IN THE SALWEEN VALLEY BELOW LA-MÊNG.
LUNG-LING—SHIH-TIEN ROUTE.

Records, Vol. XLVII, Pl. 25.



LIMESTONE COUNTRY SOUTH-EAST OF YUNG-CH'ANG FU.

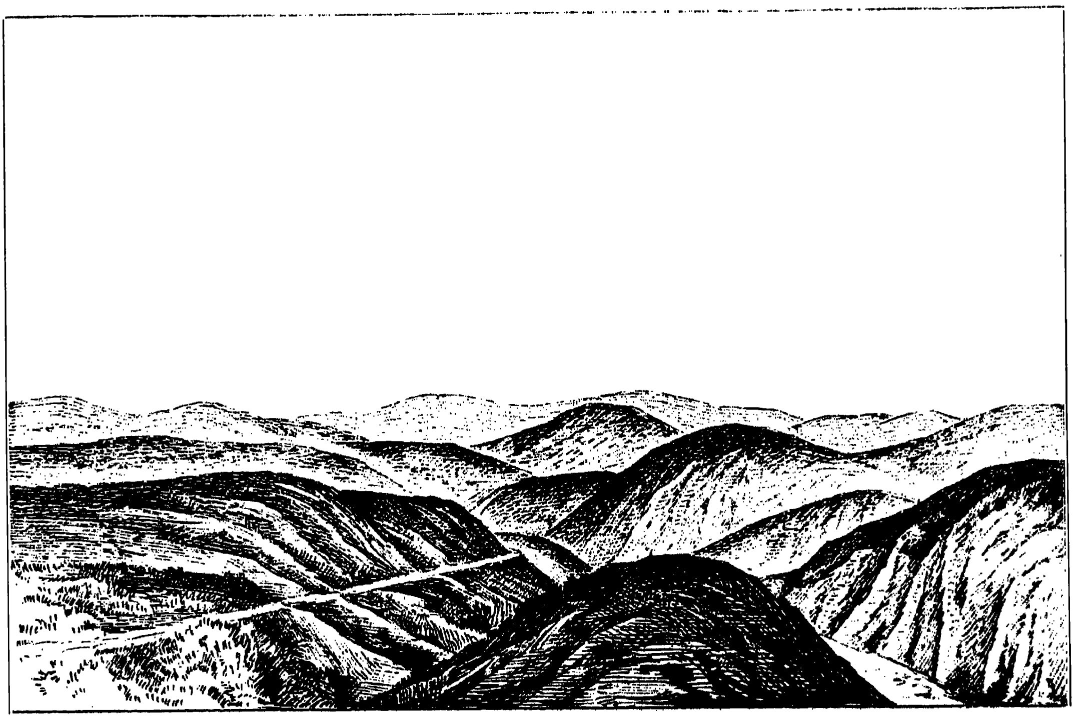
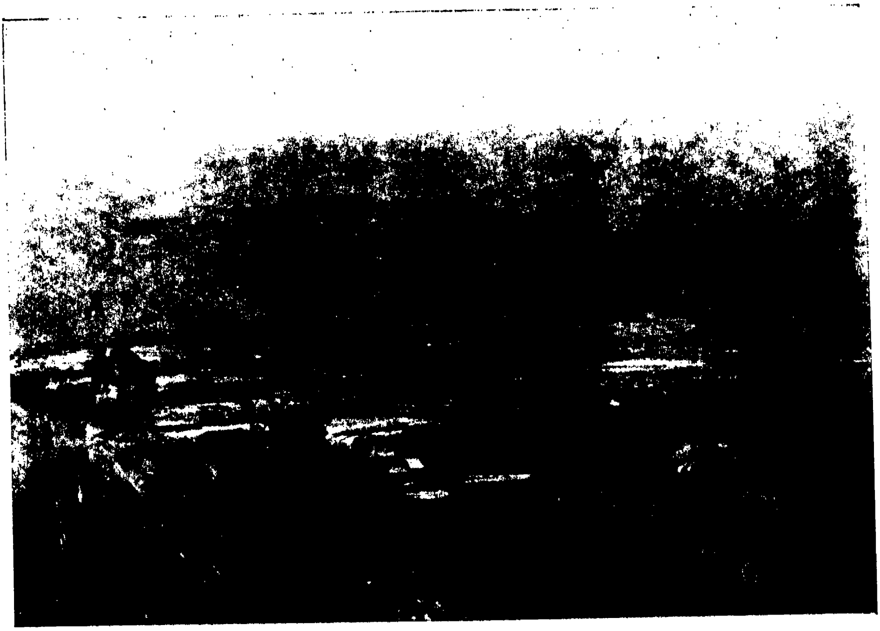
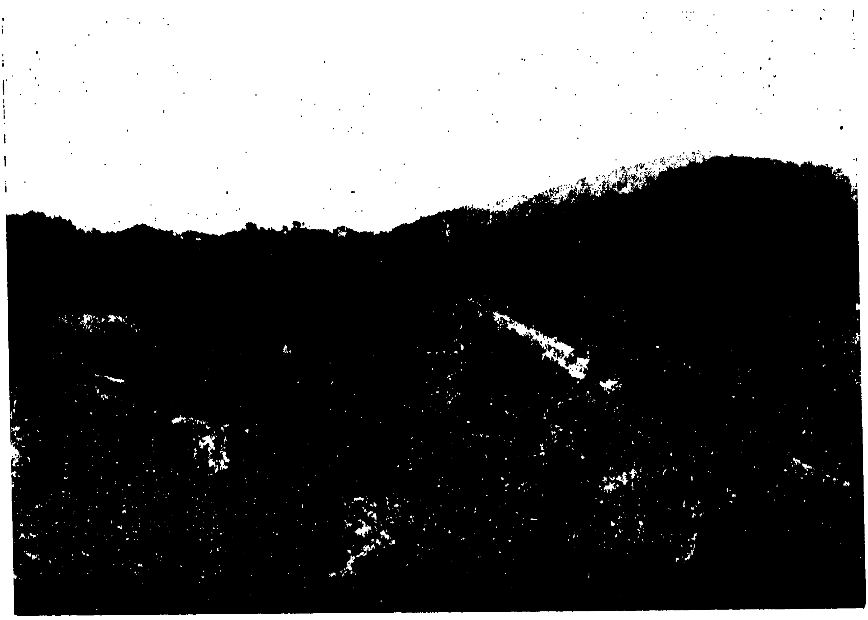


Photo. & Sketch by J. Coggin Brown. *G. S. I. Calcutta.*

TYPICAL GRANITE COUNTRY BETWEEN LUNG-LING AND TUAN-CHIA-CHAI.

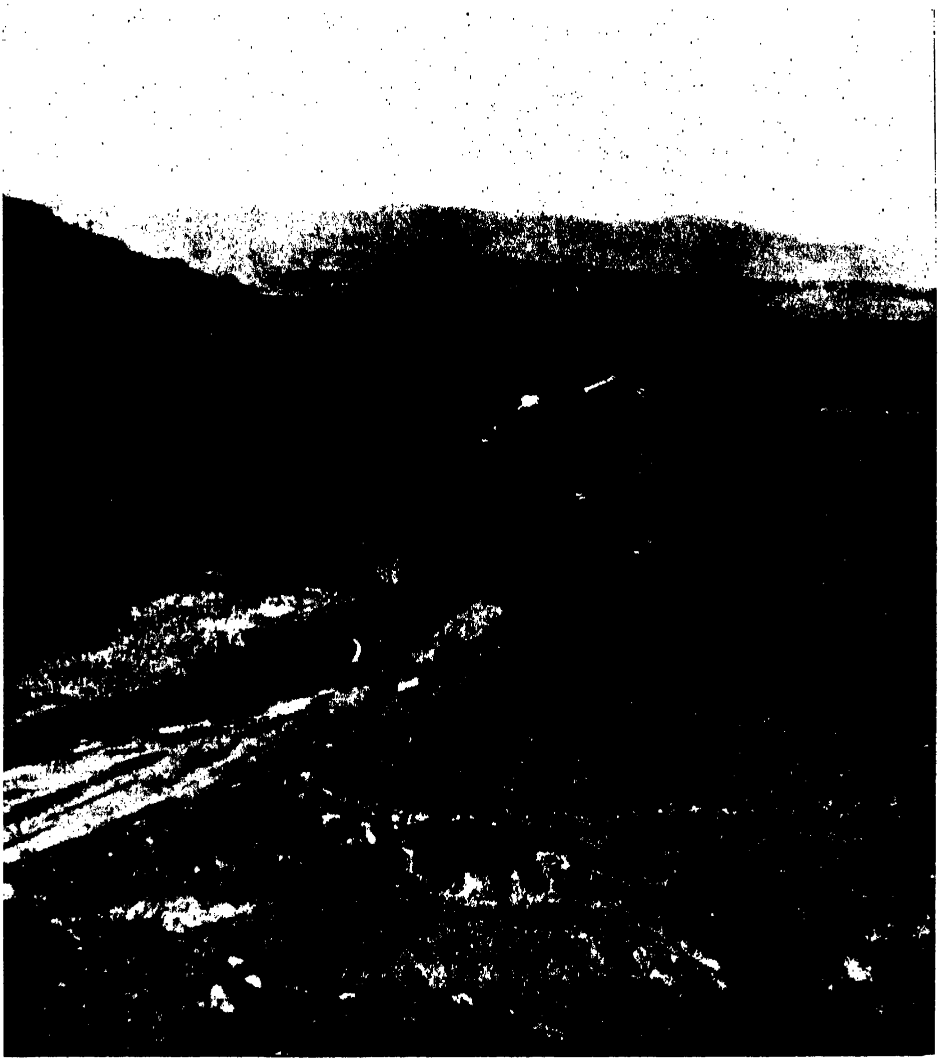


THE SHIH-TIEN PLAIN.



Photographs by J. Coggin Brown. *G. S. I. Calcutta*

TYPICAL COUNTRY, WEST OF MONG-YON, SHUN-NING FU, DISTRICT.

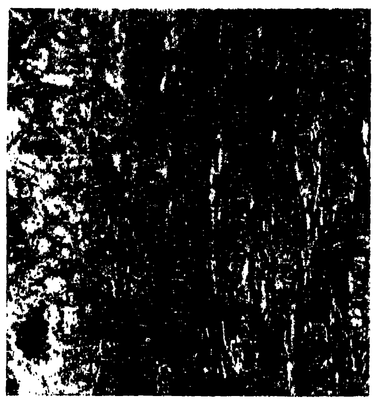


Photograph by J. Coggin Brown. *G. S. I. Calcutta.*

THE YÜNG-CH'ANG FU PLAIN.

1.

2.



3.

4.

5.

W. Tams, photo.

Bemrose, Collo., Derby.

Dipterocarpoxylon Burmense.

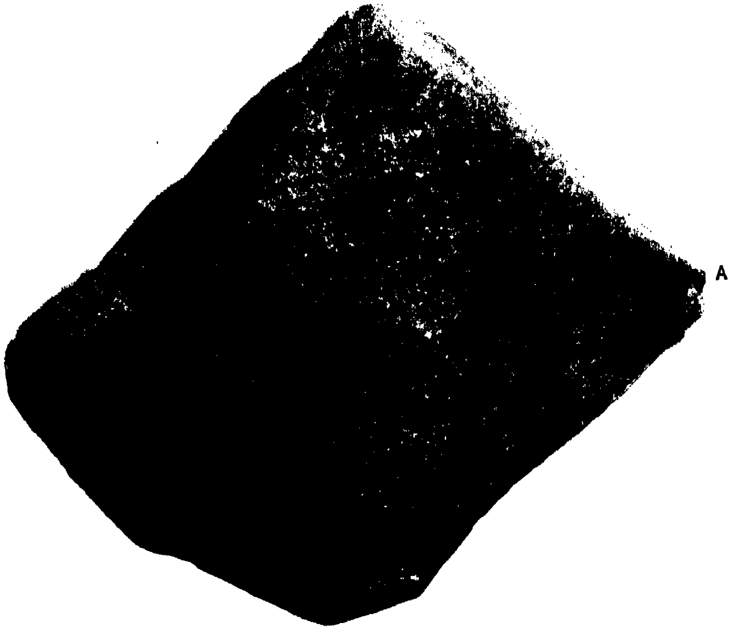
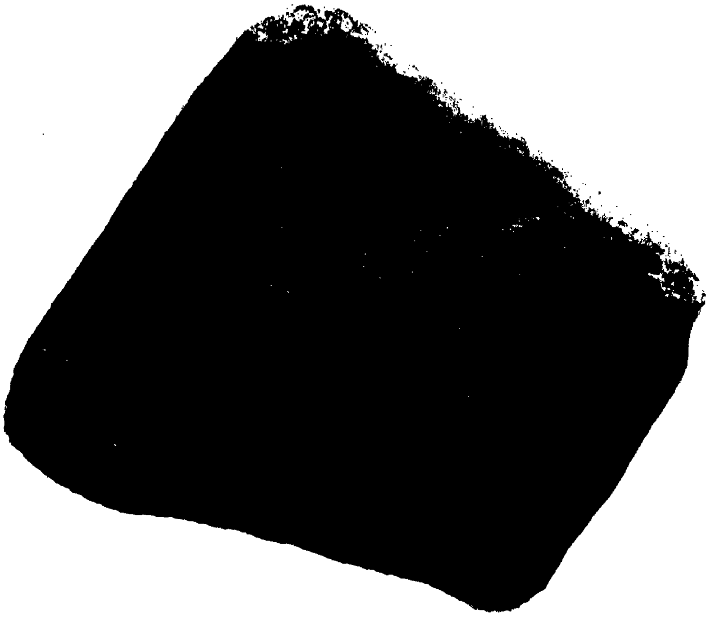
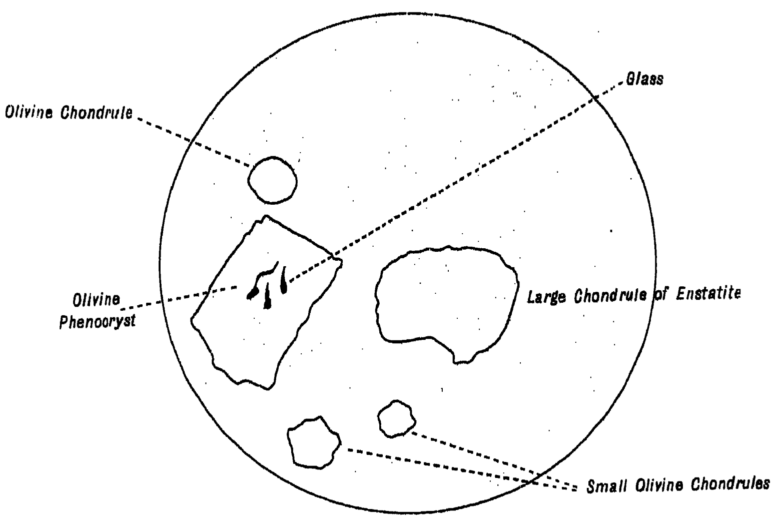


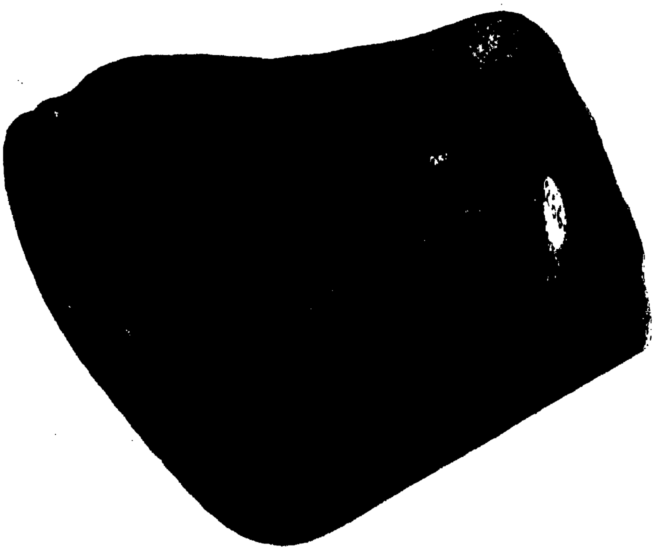
FIG. 1—THE VISUNI AEROLITE.
(Natural size)



Photographs by K. F. Watkinson. *G. S. I. Calcutta.*

FIG. 2—THE VISUNI AEROLITE.
(Natural size)


Olivine Chondrule
Glass
Olivine Phenocryst
Large Chondrule of Enstatite
Small Olivine Chondrules



(Natural size)

FIG. 1.—THE VISUNI AEROLITE.

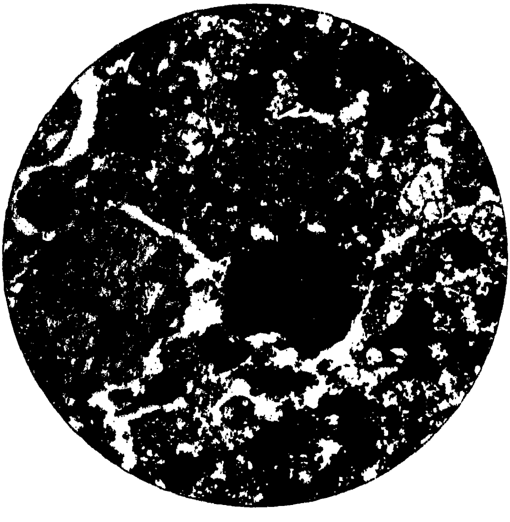
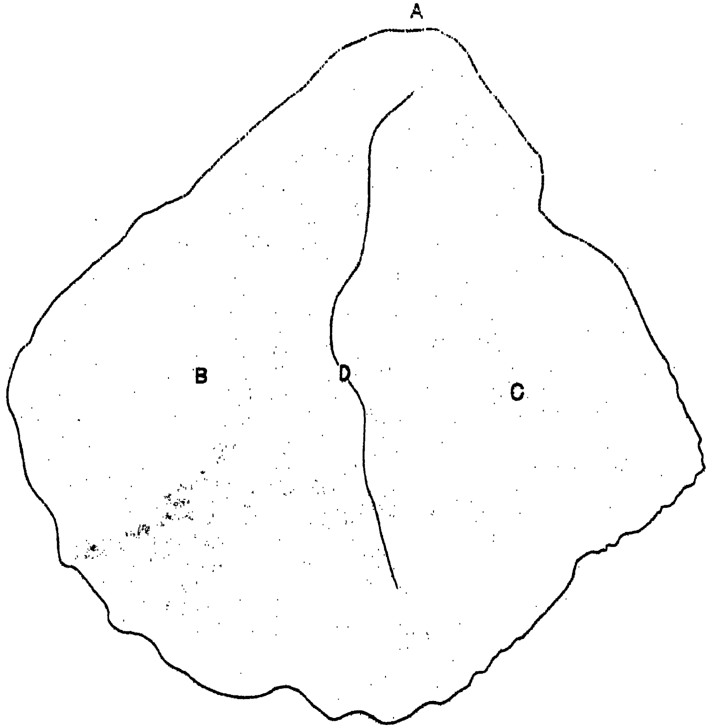


Fig. 2. × 20

Photographs by K. F. Watkinson. *G. S. I. Calcutta.*


A
B
D
C

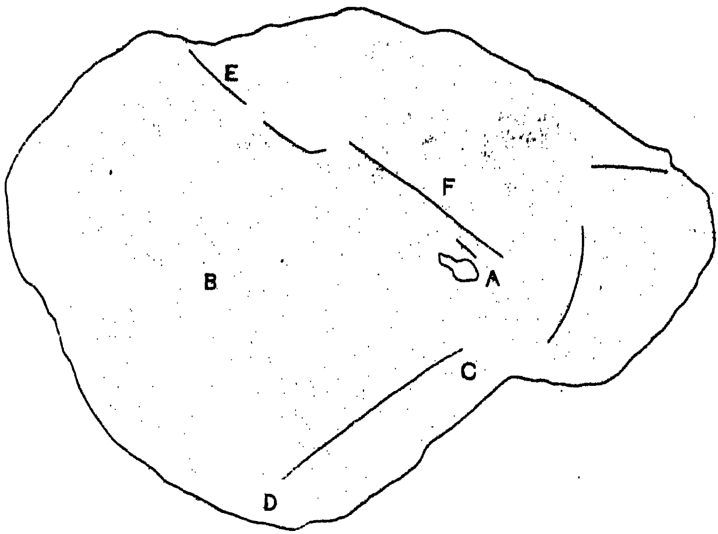
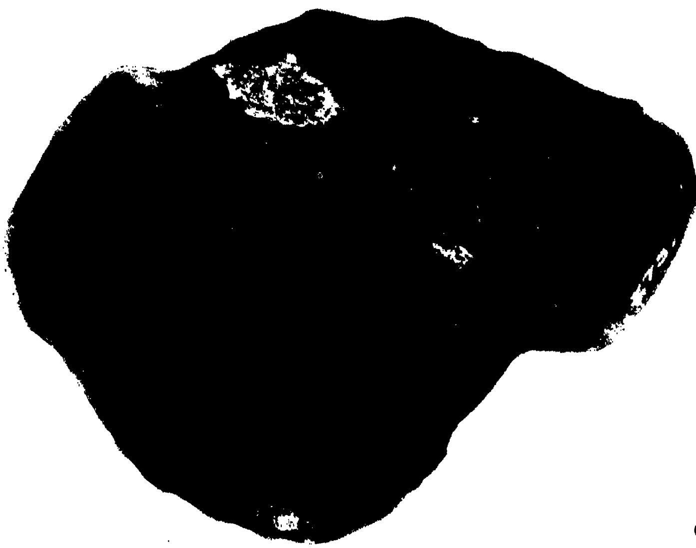

E
F
A
B
C
D

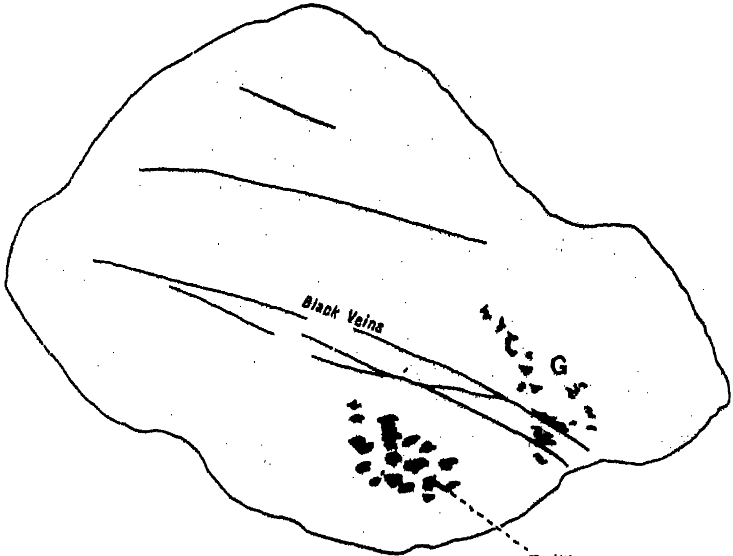
FIG. 1.—THE EKH KHERA AEROLITE.
(*Natural size*)

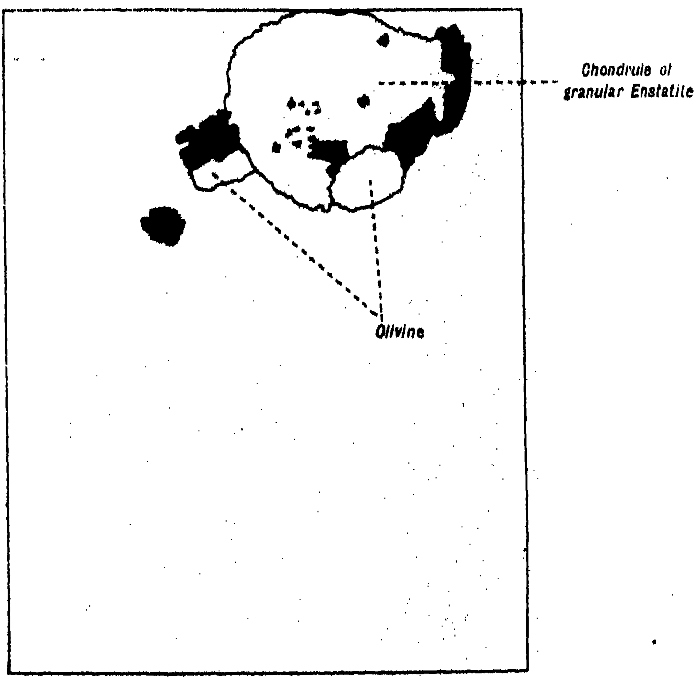


G. S. I. Calcutta.

Photographs by K. F. Watkinson.

FIG. 2.—THE EKH KHERA AEROLITE.
(*Natural size*)


Black Veins
G
Troilite


Chondrule of
granular Enstatite
Olivine

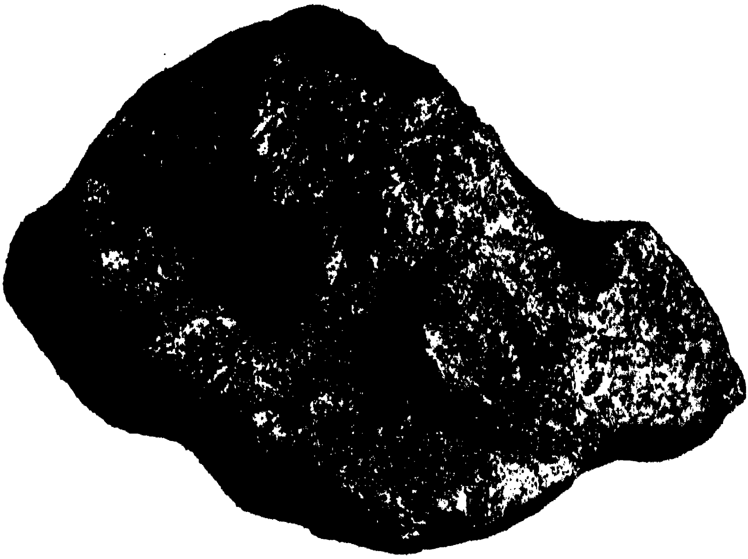


FIG. 1—THE EKH KHERA AEROLITE.
(Natural size)

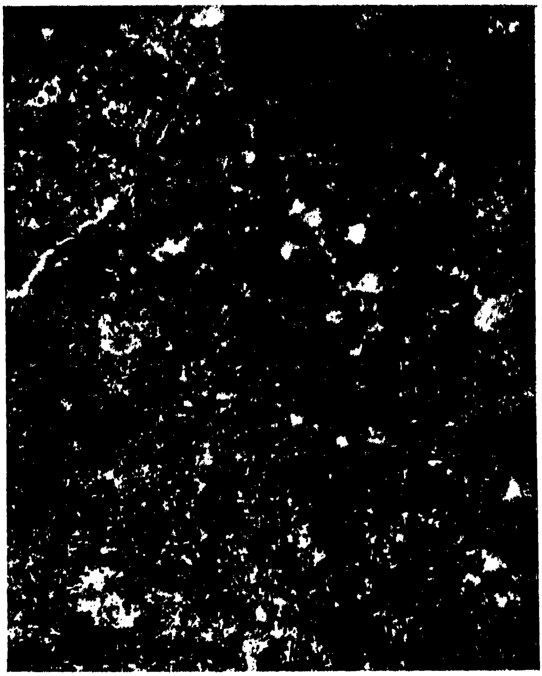


Fig. 2. × 26

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